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This volume is dedicated to:

Susan Opava, Dean of Research and Graduate Programs
Mohammad Noori, Dean of the College of Engineering
Phil Bailey, Dean of the College of Science and Mathematics
David Wehner, Dean of the College of Agriculture Food and Environmental Sciences
Linda Halisky, Dean of the College of Liberal Arts
Ed Sullivan, Associate Dean of the College of Engineering

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“Learn by doing” isn’t just a motto at Cal Poly. It represents the school’s genuine dedication to this powerful educational philosophy. That is why when the National Science Foundation awarded a $500,000 grant to the Cal Poly’s Honors Program to fund scholarships for academically-talented students in the fields of science, technology, engineering and mathematics, it did so knowing that the money would help Honors students become engaged in undergraduate research projects in line with this philosophy. The goal of these projects would be to broaden the learning experience of undergraduates by creating interdisciplinary opportunities for research while striving to contribute to the greater good of the community, both locally and globally. The result is this journal, which highlights Honors undergraduate research projects initiated in the 2006-2007 academic year. Many of these projects not only met these goals, but in many ways exceeded them. For this reason, I am very proud to introduce Cal Poly’s first Honors Undergraduate Research Journal.

While the NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) grant provided scholarships to several of the students who participated in the Honors Undergraduate Research Program, institutional funds were given to faculty to support the projects they undertook with the students. I feel it is important to acknowledge all of those who supported this program with matching funds and their enthusiastic leadership. This includes Susan Opava, Dean of Research and Graduate Programs; Mohammad Noori, Dean of the College of Engineering; Phil Bailey, Dean of the College of Science and Mathematics; David Wehner, Dean of the College of Agriculture Food and Environmental Sciences, Linda Halisky, Dean of the College of Liberal Arts; and Ed Sullivan, Associate Dean of the College of Engineering. I would also like to send special thanks to Provost Bill Durgin for his leadership in promoting research at our university.
Participation in the Honors Undergraduate Research Program is open to not only Honors students, but to all students on campus who have a desire to engage in undergraduate research. Those who demonstrate financial need also qualify to receive scholarships from the NSF S-STEM grant. The infrastructure of the Honors Program makes it possible to transcend some of the cross-college challenges that typically emerge in the administration of interdisciplinary efforts as students are matched with the faculty projects. Students participating in the research projects enroll in Honors 200 and Honors 400, and this provides ample opportunities for them to share their research findings with their peers and faculty members coming from various disciplines. In the first year this approach was used, the number of research projects increased from 20 to 34.

I would like to recognize the students and research faculty who participated in this program by submitting and reviewing papers for inclusion in this journal. I would also like to acknowledge all of the faculty mentors who made these research opportunities available for the students. Their time and efforts are evident in the work highlighted in these papers. Without their support, Cal Poly’s Honors Undergraduate Research Program would not have been possible.

While this first volume of the Honors Undergraduate Research Journal contains just a small sample of the outstanding undergraduate research that took place last year, I hope it sheds light on what is possible and sparks ideas for even greater endeavors in the future. With the support of the entire Cal Poly community, I am confident that we will continue to build on the success we have seen in this first year of the Honors Undergraduate Research Program.

Sema Alptekin
Director of the University Honors Program
Managing Editor, Honors Undergraduate Research Journal
HONORS UNDERGRADUATE RESEARCH PAPERS
ROBOTIC FINGERSPELLING HAND
FOR THE AID OF THE DEAF AND BLIND

Alan Tepe, Student Author
Dr. Saeed Niku, Research Advisor

EXECUTIVE SUMMARY

This quarter, work continued on the design and construction of a robotic fingerspelling hand. The hand is being designed to aid in communication for individuals who are both deaf and blind. In the winter quarter, research was centered on determining an effective method of actuation for the robotic hand. This spring 2008 quarter, time was spent designing the mechanisms needed to mimic the size and motions of a human hand. Several methods were used to determine a proper size for the robotic hand, including using the ManneQuinPro human modeling system to approximate the size of an average male human hand and using the golden ratio to approximate the length of bone sections within the hand. After a proper average hand size was determined, a finger mechanism was designed in the SolidWorks design program that could be built and used in the robotic hand.
INTRODUCTION

There are a large number of individuals who are unable to hear and unable to see. In the United Kingdom alone, there are over 20,000 (Sense, 2003). As one might imagine, it is very challenging for these individuals to communicate with others. These people are incredibly creative and adept at creating methods of communication. However, for normal speaking situations, they usually use sign language to form words for others to see. To listen to others, they usually feel the hands of someone spelling out words with the single-hand manual alphabet. These limitations obviously make it difficult for the deafblind to communicate with individuals who are not familiar with sign language.

To make communication easier for these individuals, the creation of a portable robotic hand will be developed, which will form sign language letters based on input from a keyboard, computerized text, and eventually voice. This would help persons unfamiliar with sign language to effectively communicate with persons who are affected by deafblindness, as well as serve as a valuable tool for young deafblind persons as they learn fingerspelling.

DESIGN

In designing a robotic fingerspelling hand that is easy for a deafblind individual to use, it is essential to design the device with dimensions similar to those of an average human hand. This will make it easier for deafblind users of the hand to effectively understand letter symbols made by the hand. The hand will be used to teach fingerspelling to deafblind users, and if its size is varied too much from a typical human hand, it will be difficult for a deafblind user who learned fingerspelling on the robotic hand to decipher letters formed on a human hand, and visa versa.

For these reasons, great care was taken to obtain typical hand dimensions to be used in the design of the robotic hand. These dimensions were obtained with the ManneQuin Pro Human Modeling System. The software contains a digital 3D model of an average human body. The dimensions for this model

\[ \text{In this text, “fingerspelling” will refer specifically to use of the single-hand manual alphabet for communication.} \]
were taken from 1988 US military measurements. Before the actual design of any mechanisms took place, dimensions were obtained from the 3D model and used as dimensions for the fingerspelling hand. This was done by measuring coordinates at the points on the 3D models below and finding the distance between these coordinates (Figure 1).

As can be seen in Figure 1, it is difficult to determine the dimensions of linkages within individual fingers with the ManneQuin Pro Human Modeling System. It is almost impossible to tell from the model where the fingers bend. For this reason, the lengths of individual linkages were approximated numerically with a number known as the “golden ratio,” a number which is often observed in natural phenomena and is said to be observed in the lengths of adjacent sections of human fingers (goldennumber.net).

To approximate the lengths of individual sections within each finger, it was assumed that adjacent sections of each finger had a length ratio approximately equal to the “golden ratio” or 1.61. Meaning the longer section is 1.61 times the length of the shorter section (Dunlap, 1997). The golden ratio isn’t entirely accurate and it has never been scientifically proven that corresponding sections in the human body have lengths which follow the ratio exactly. However, measurements were taken of the student’s hand who conducted this study, and the golden ratio was observed in the adjacent sections of the student’s fingers with 94-97% accuracy, depending on which finger was measured.
In the design of the fingerspelling hand, it is crucial that the hand be able to mimic the motions of a human hand to the extent that a deafblind user will be able to interpret the symbols made by the robotic hand just as easily as they would be able to interpret a human hand. For this reason, the robotic fingerspelling hand should have close to the 22 degrees of freedom found in a human hand (Gilden, 1987). Initially, several finger mechanism designs were investigated that approximated the motion of one finger with a single movement by a single actuator. Namely, a design was investigated similar to that used in the Belgrade-USC hand discussed in Autonomous Mobile Robots (Bekey, 2005). A diagram of this mechanism can be seen in Figure 2 (Bekey, 2005). After some investigation, it has been determined that the finger motion produced by the Belgrade-USC hand is too simple and limited for use in a robotic fingerspelling hand. It was determined that a fingerspelling hand must have the ability to move individual sections of fingers without effecting the angular position of other fingers. The USC-Belgrade finger mechanism didn’t have this ability, so it cannot be used in a fingerspelling hand design.

After the initial investigation of several designs used in robotic hands, a sketch was made of a finger design that would allow each individual section of a finger to move independently of the others. This design would be ideal for a fingerspelling hand, allowing a great deal of flexibility in hand motion (Figure 3). This design uses two wires to manipulate each individual section of a robotic finger. Each of these wires is extended down into the base of the hand, where it can be tensioned by a motor or other system of actuation. The
wires are arranged in such a way that actuation of any one of the wires will only affect the section of finger that the wire is attached to.

![Figure 3 - Initial sketch of finger mechanism idea. In this design, each segment of the finger can rotate independently of the others by adjusting the tension in connecting wires (red). In this design, each finger has three degrees of freedom.](image)

This design was developed into a 3D model using the SolidWorks computer drafting program (Figure 4). In this phase, many of the dimensional details left out of the sketch were determined. The creation of the robotic hand using CAD software is an important step, as the computer model can be used to create rapid prototyping models, as well as aid in final manufacturing of the hand. To create a finalized design of the robotic hand, five fingers must be designed and dimensioned completely. The dimensions of the single finger in Figure 4 can be adjusted easily in CAD software to create designs for the index, middle, ring, and pinky fingers. However, another finger mechanism must be designed to mimic the motions of the thumb, which is considerably more complex than the other fingers.

![Figure 4 - SolidWorks assembly of a finger mechanism to be used in fingerspelling robotic hand (transparent view- left; solid view right).](image)
CONCLUSION

Proper dimensions for a robotic fingerspelling hand were determined and an appropriate finger mechanism for the robotic hand was designed in SolidWorks. These are both important steps in the creation of a robotic fingerspelling hand to help individuals who are both deaf and blind communicate.

FUTURE WORK

There remains a great deal of work that must be done on the design of the robotic hand. The mechanisms for the center (palm) of the hand and the thumb have yet to be designed. Work will continue in these areas in the Fall quarter of 2007.

REFERENCES


CURRENT HEALTH AND ENVIRONMENTAL STATUS OF THE MAASAI PEOPLE IN SUB-SAHARAN AFRICA

Ruth Brady, Sara Suksiri, Stella Tan
John Dodds & David Aine, Student Authors

ABSTRACT

As time passes, the AIDS pandemic continues to spike, affecting an estimated 38.6 million people worldwide. In response, a satellite health clinic is being designed by two Cal Poly students to serve the Maasai people living in the Kajiado district in Southern Kenya. The Maasai have traditionally lived as pastoralists, surviving off of their cattle with which they share their water, increasing the risk for contamination. However, as the population of Kenya increases, the land the Maasai have traditionally used for grazing is shrinking. For this reason, some have turned to farming to maintain their livelihood. These factors have contributed to the desertification and deforestation of their region. As the lifestyle of the Maasai evolves, they rely more on maize than meat and dairy products for their nutrients. All of these changes have contributed to the evolution of the Maasai culture. We will address these changes in order to better understand the Maasai, as well as highlight possible further aid needed to support their survival.
“This is a war. It has killed more people than has been the case in all previous wars and in all previous natural disasters. We must not continue to be debating, to be arguing, when people are dying.”

Nelson Mandela, former President of South Africa

The statistics of the global AIDS epidemic are devastating. At the end of 2005, there were an estimated 38.6 million people worldwide living with HIV (1). At a special session of the UN General Assembly in 2001, leaders from 189 Member States committed to goals aimed at reversing the global epidemic by 2015. To assess progress goals established at the historical session, the most comprehensive set of data on the response to the AIDS pandemic was compiled in the 2006 Report on the global AIDS. Key findings in the global review included important progress being made since the 2001 Special Session, yet points out an extraordinary diversity between regions and their response to HIV. In January 2003, a five-year, $15 billion Emergency Plan for AIDS Relief was initiated including support for satellite medical clinics to be built (1). The cry for the development of such clinics in Sub-Saharan Africa also comes from organizations including: Doctors Without Borders, The Harvard AIDS Institute, UNAIDS, and the World Health Organization (2).

In response to this need, two senior Cal Poly Architecture students are designing a health clinic to serve the Maasai people in the Kajiado district in Southern Kenya. This response to design a clinic spurred further interest in the Maasai people, their lifestyle, needs, and possible other areas of future involvement and aid by the Cal Poly student body.

An in depth literary review has been performed to understand the needs of the area that could provide ground for a more holistic approach to serve the Maasai. By understanding their culture, current water situation, nutrition status, and resources available, the possibilities of solving problems surpass building a clinic to prescribe medication and treat illness. Being built on this foundation of understanding of the Maasai people, a greater potential arises for a purpose-driven, holistic response.
METHODS

Design of Acquiring Information

Our group used various methods to gather the information we needed for this literary review. Because of the nature of the project, we could only perform a review of published versus first-hand research. The information was gathered using the Cal Poly Library, literature search engines, reliable websites, and information requested from private organizations. This project was coordinated with the help of Blogger\(^1\), where we relayed information and updated progress.

In order to keep our project on track, we met bi-monthly and updated each other with our progress and problems. Through these methods we have produced this research paper.

Complications

A difficulty with this project was trying to find specific, relevant information on the Maasai people and the environment in which they lived. There was a good deal of material on tourism in the Kajiado general area, but respectable, scholarly studies of the problems we hoped to address were hard to come by. We tried to contact various organizations requesting specific information but very few replied.

LITERARY CATEGORIES

Culture

“We prefer ‘Maasai’, not ‘Masai’,” says a native. “Maa-sai,” he explains, “means ‘my people’”(3). His people, the Maasai tribe in Kenya and parts of northern Tanzania, are one of the most visible cultural groups in Africa today. Maasai women weave bold colors and beautiful designs into the beaded jewelry that adorns men and women alike. The young Maasai men, the warriors of the tribe, have long hair that is grown out and shaped for the whole duration of their service as a warrior. When a warrior returns from a successful

\(^1\) Blogger: an online password protected communication network, site projectkenya.blogspot.com
lion hunt, the whole tribe celebrates this historical accomplishment. This distinctive way of life and their strikingly tall figures have established them as the face and the emerging voice of Africa’s struggles. Although many Maasai customs are often viewed through our Western romanticized lenses, the crises that these people face in preserving their identity and ensuring a future are very real and demand our attention.

Researchers estimate the total Maasai population to be about 883,000 with approximately half of the people living in Kenya and the other half in Tanzania (4). It is hard to say for certain how many there may be because the Maasai have a peculiar tendency to distort their numbers for the census takers that stems from their overall distrust of modern government. They live simply, preferring to be left to their own cooperative forms of government and want only land on which their cattle can graze.

Cattle are valued above all else and a man’s wealth is measured in proportion to the number of cattle he owns. It also has a spiritual significance since the Maasai believe that they were granted exclusive rights and dominion over all the cattle (5). Of course, cattle also serve as an essential part of the Maasai daily diet. However, because the Maasai care for their cattle as they would a child (in fact, a typical prayer asks, “May Creator give us cattle and children”), they prefer to eat the meat of other livestock, using cattle mainly for their milk. Recently, in the worldwide onset of expansion and privatization that leaves not even rural Africa alone, Maasai herdsmen have been pressed to find new grazing lands and water sources. The increasing difficulty of doing so has forced many Maasai to turn from their traditional pastoral, semi-nomadic lifestyle and incorporate a more agricultural economy.

Environmental
Kenya’s population grows at a rate of 2% every year, which is slower than it was in past decades, around 4%, but very fast compared to most countries (6). Along with this growing population comes an increasingly higher utilization of natural resources without the consideration of maintaining a sustainable ecological balance (7). Currently, Kenya has several prominent environmental problems; most of which stem from poverty and overpopulation. The specific problems we chose to focus on are desertification\(^2\), global warming, and deforestation.

20  STUDENT RESEARCH
Desertification & Deforestation

Desertification in Kenya is partly a result of both overgrazing and deforestation. Overgrazing in the Rift Valley region by the domestic livestock belonging to the Maasai people has led to desertification and even decreased diversity in species (8). Overgrazing also undermines possible agricultural production as it degrades the soil quality. Soil erosion occurs by water run-off and wind, which can lead to desertification of the land (8, 9). Soil erosion has caused a problem when Maasai have tried to farm the land versus their traditional practice of grazing.

The state’s issue of desertification is very pressing; furthermore, Peter N. Macharia of the Kenya Soil Survey conducted a study involving local farmers to compile possible interventions the Maasai people could employ to halt and even reverse the desertification process. The hopes of the study were to create more awareness and empower the Maasai of the practical ways to combat desertification. The research identified useful trees to plant around homes for shade, to use as woodlots on their farms to provide fuel, and to act as windbreaks. These specific trees include: Grevillea robusta, Cassia spectabilis, C. siamea, Schinus molle, Croton megalocarpus, Leucaena leucocephala and Azandiracta indica. The study also specified trees useful for fencing, because cut wood has to be annually replaced due to termites. The suggested trees include: Commiphora africana, C. stuhlmanii, Euphorbia tirucalli, Erythrina abyssinica, Carissa edulis and Agave sisalana (9). This study exemplifies the value in consulting with the local Maasai to determine solutions to identified problems. Further solutions to this problem include creation of windbreaks and planting native plants to slow soil erosion.

Deforestation is also a significant problem in Kenya, even though forests only account for a small percentage of its area. According to a UN report, population growth is the main cause of deforestation, as forests are cleared for agricultural land to support a burgeoning population (10). Deforestation is also linked to drought and flooding because the forests provide an area

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2 desertification: the rapid depletion of plant life and the loss of topsoil at desert boundaries and in semiarid regions, usually caused by a combination of drought and the overexploitation of grasses and other vegetation by people
for water catchments. As the forest is depleted, the likelihood of drought and flooding increase significantly.

**International Involvement**

The United Nations Conference on Global Warming just concluded in Nairobi. They formed a plan to reduce global warming and emissions. Secretary General Kofi Annan is recorded saying, “The impact of climate change will fall disproportionately on the world’s poorest countries, many of them here in Africa” (11). Most importantly, in order for Kenya’s delicate ecosystems to be preserved, the world must take action to combat this global problem. The Kyoto Protocol is a great first step in this direction, but to protect the people of Kenya who depend on the land for their well-being, specifically the Maasai, more extensive action must be taken by global bodies such as the UN.

In order to get rid of these problems, the government and NGOs must be involved. Organizations need to start taking progressive action to reverse the effects of these problems. The government, with the help of the UN, must put into place studies and programs to combat desertification and deforestation and help reverse the effects of global warming. Fortunately, in Kenya, positive actions are being taken to change the deforestation trend. Wangari Maathai, who won the Nobel Peace Prize in 2004, founded the Green Belt Movement, which plants trees throughout Kenya and other parts of Africa. Before 1997, 20 million trees were planted and have survived (12). Support of this kind of endeavor is imperative to the survival of the traditional lifestyle of the Maasai living within Kenya.

**WATER STATUS**

As water is a necessity for survival, the quality of water consumed is a major deciding factor in a person’s health. Because of water’s dramatic impact on physical well-being, it is especially important to understand the status of water consumed by the Maasai people in order to assess their health status. The following survey of water quality and availability addresses Maasai communities near the Kenya-Tanzania border.
Water Accessibility

Accessibility is a deciding factor in whether or not water is obtained. A survey conducted by Kusiluka et al. in 2003 found that among 128 people from the Bagamoyo district, where many Maasai communities reside, and the Dodoma rural district along the Tanzania-Kenya Border, 9 percent report water as “readily available,” 50 percent report it as “not easily available,” and 40.6 percent report water availability as “problematic” (13). Water availability is influenced both by source distance and competition for water. The average distance traveled to the closest water source in the Bagamoyo district was 2.9 km ± 3.0 km, the farthest distance being as much as 15 km away. A majority of those that resided in the Bagamoyo district obtained water for domestic uses from ponds, dams, and taps. Ponds and dams were also the main sources of water for animals. In the Bagamoyo district, few villagers are financially capable of constructing their own water sources; most water sources in the Bagamoyo district were created by the government or by the villagers working with the government. Knowledge of sustainability was also scarce with only 39.1 percent of those surveyed aware of resource maintenance and reusability (13).

In the Kajiado district, there is less than 500mm of rainfall every year (14). Due to the shortage of water, Maasai herders have a difficulty keeping their cattle alive. Because cattle are a staple to many families’ economic well-being, the decline of cattle makes it difficult for families to pay for food and schooling for their children (15). Not only is water important for cattle, but it is necessary for other livestock as well. In the Dodoma and Bagamoyo district study, of the 128 people surveyed, 71.9 percent reported water shared with cattle, sheep, and goats. While water shortage is problematic, shared water between households and animals becomes a larger issue where sanitation is concerned. The Dodoma and Bagamoyo districts study indicated that 71.1 percent of the respondents shared water sources with other households (13).

Water Cleanliness & Contamination

Diseases associated with contamination by animal excreta include cholera, typhoid, shigellosis, meningitis, and hepatitis A and E. Viruses, protozoa,
and bacteria are also obtained from water sources contaminated with human or animal feces. Symptoms of these diseases and viruses include “diarrhea, stomach cramps, nausea, vomiting and low-grade fever” (13). An African Medical and Research Foundation (AMREF) study by Rukunga et al. in 2002 revealed that 79 percent of water sampled in the Kajiado and Kitui districts contained gross fecal contamination (16). Another study conducted by Conroy and Elmore-Meegan in 1996 on the benefits of solar disinfection found the presence of fecal coliform bacteria in the drinking water of Maasai communities, which was increasing the severity of diarrhea (17). Contaminated water has a grave impact on Maasai communities, preventing performance of daily duties and decreasing the quality of lives.

Several studies confirmed the decrease in water contamination by human feces with a latrine near the water source. Another AMREF study conducted by Rukunga et al. in 2003 in the Isinya division of Kajiado District revealed decreased microbial load when the water source was near a latrine (18). The Bagamoyo and Dodoma districts study also revealed that diarrheic cases were most abundant in the Chamakweza village, which had no latrines. Both studies also proposed that an influential factor of water sanitation was hygiene education. The “hygiene practice such as washing hands without soap prior to eating food” was uncommon in the Bagamoyo district’s Chamakweza and may be a contributor to viruses and diseases (13). Hygiene education in the Isinya division of Kajiado District also helped in drastically decreasing microbial load (16).

Another contributing factor to the poor quality of water in the Kajiado District may be the agricultural use of pesticides and fertilizers. Because “tenancy arrangement in the irrigated land parcels demands that agricultural yields are high to recover costs,” many farmers are using fertilizers and pesticides without restraint and to excess. Most are also uneducated in the safe use of pesticides; farmers applied pesticides without wearing any protective gear. Artificial fertilizers are believed to be causing dense growth of algae, aquatic weeds, and sedges. With the dry climate of the region, “explosive growth of toxic algae species can be expected,” harming humans and killing livestock (13).
Major issues that the Maasai people have with accessing healthy water are a result of resource shortages and lack of sufficient education on the subject. With financial aid and training, the Maasai may improve the quality and availability of sufficient drinking water, thus improving the quality of their lives.

HEALTH STATUS

Prevalence of HIV/AIDS

Although the Maasai operate on a daily basis as a fairly egalitarian society, the traditional governing figure is usually the laibon. Unfortunately, not even the laibon has a solution to the tragedy of AIDS and HIV that has spread throughout the Maasai people.

The United Nations Department of Economic and Social Affairs estimates that 39 million people today are living with HIV/AIDS and 20 million affected reside in Sub-Saharan Africa (21). Of the 38 countries in Africa that are affected, Kenya, home of the Maasai, is one of the top ten most affected countries. Ten to twenty percent of the population has contracted some form of the disease. At a prevalence rate that hovers just under 20%, nearly one in every five adults in Kenya has HIV/AIDS. The consequences of this epidemic are widespread. The numbers of children left behind in the wake of this disease are devastating. Another United Nations report identifies at least half a million children in Kenya who were orphaned as a result of the AIDS epidemic (22). Future generations have been impacted in other ways as well. Because HIV/AIDS greatly affects the younger, sexually-active members of the Maasai, the part of the society that would normally be able to contribute economically and socially has been rendered effectively invisible.

The sexual practices of the Maasai require immediate attention and redress in order to curb the rising rate of infection. Whenever possible, young girls are married to much older men as soon as the girls reach puberty in order to prevent the birth of children out of wedlock. But until marriage, it is normal for girls to have sexual relationships with any of the young warriors and these relationships will often even continue throughout marriages.

3 Laibon: an elder practiced in the ways of healing whom the people will consult when misfortune arises
as well. As for the men, polygamy is hardly frowned upon. Clearly, confusion and a lack of knowledge about HIV/AIDS play a large part in the spread of this disease.

Of those who already have the disease, there are several further complications. One large, obvious problem is that many of the Maasai with HIV/AIDS are not aware of their diagnosis because of the lack of clinics to run tests for them. For those who are fortunate to have a clinic nearby, there is still a cultural stigma that prevents people from getting tested. Women especially fear testing because if they test positive, they believe that their husbands will abandon them. Another problem that clinics face is the unavailability of necessary medical resources to treat HIV/AIDS. Antiretroviral treatments, which are widely successful in the United States and often reduce mortality by up to a hopeful 80%, are simply too expensive for many rural Kenyan clinics. Furthermore, sticky legal barriers prevent the production and import of antiretrovirals in the area. With more than 33% of new babies in this country being born infected with HIV/AIDS and 50% of those children dying before the age of two because they and their mothers cannot receive proper treatment, something has to be done. (23)

Fortunately, people today are taking steps in that direction. Global aid associations are promoting health education and medical communication via print, school programs, and anti-AIDS clubs in schools. Volunteers with Doctors Without Borders are donating their time in Kenya to provide free counseling and testing. People who lack the time or skill to be involved personally are taking measures to support groups such as Adopt-A-Doctor and Kenya AIDS Intervention. Every day, more people are becoming aware of the Maasai and the larger problems that they represent and every day, there is another chance to bring hope and help to the Maasai people.

Other Health Issues
A study interviewing residents of 30 homesteads, seven schools, and three health care centers found that the main health concerns were malaria, GI problems, and respiratory infections. Respiratory infections have been noted mainly in children due possibly to their attire not providing enough warmth during cold mornings and nights. The mothers interviewed stated that the
most common diseases among their children included malaria 79%, diarrhea 71%, pneumonia 52%, and others including worms, malnutrition, and dental problems. The hypothesized causes of these stated conditions are contaminated water, consumption of contaminated foods, and poor ventilation of air in their living spaces (24).

Medical Care Perceptions
A study published in the Western Journal of Nursing Research discovered that 29% of 189 women delivered their babies in a clinic and the remainder delivered their babies at home. The low delivery rate in clinics partially results from the lack of transportation to clinics while pregnant and limited places to stay before and after labor near health clinics (25).

During the rainy season, the Maasai typically migrate. This can pose difficulty in accessing proper health care. The wild animals in the area also limit them from traveling far distances to access health care when sick. These issues raise the need for more health clinics for the mobile Maasai. Regarding the Maasai’s acceptance of traditional health care, P. Wanzala, J. Hassanali, P. Kibet, and H. Dossajee observed that elder support is imperative for acceptance by the community. Therefore, it is essential to have the support of local leadership, which spurs community involvement and approval (24).

NUTRITIONAL STATUS
When observing the health of the Maasai, we considered their nutritional intake to study whether they are a well-nourished people. It is hard to pinpoint a specific reason why a people eat the way they do. Many factors come into play including the group’s economical status, their cultural beliefs about certain foods, access and availability of foods, and health status of workers needed to harvest certain foods. With these ideas in mind, we attempted to understand the Maasai’s evolving diet pattern.

Traditional Diet
The Maasai have traditionally lived off of their grazing cattle by consuming the milk, meat, and blood from their livestock. The consumption of blood, which contains high protein and is beneficial to the immune system, occurs
only on special occasions (25). In Kajiado where the Maasai reside, livestock and livestock production account for 71 percent of their income (26). Although their cattle are a huge resource, they have begun to minimize cattle consumption. The Maasai do not consume milk and meat during the same meal because they do not want to consume dead (meat) and live (milk) products at the same time; they believe this will help reduce the amount of cattle slaughtered. They also slaughter certain cattle (steers) only during special ceremonies (27).

Consumption of plant foods is uncommon due to the thought that green vegetables were meant for livestock feed (28). However, there has been an increased need to overgraze land and plant foods are more readily consumed. Farming is becoming more prevalent, although farming has been looked down upon because once land has been farmed, it is no longer suitable for cattle grazing. The consumption of maize, rice, potatoes, and cabbage is becoming more prevalent (25). A study done by J.K Nyoro, a Senior Research fellow with Tegemeo Institute and Dr. Wilson Nguyo, the Director of Tegemeo Institute at Egerton University, shows that the Maasai living in Kajiado consume 60% of their calories from maize, 7% from rice, 5% from potatoes, 4% from wheat, 3% from bananas, and 21% from other sources probably of animal origin (28).

**Nutrition and Pregnancy Practices**

When pregnant, the Maasai traditionally consume a modified diet. They are advised by TBAs to consume a restricted diet after the 6th month of pregnancy with the belief that they will have an easier delivery and a healthier baby. They consume fewer meals, drink more water, and tend to watch their cattle, which limits their access to foods (24, 28). Anemia is also prevalent due to a primary maize and milk diet.

Almost immediately after birth, mothers are given a diet rich in iron, protein, and fat. The first food a child is given is fat, even before breast milk (28). This practice goes against FNRI’s recommendation to exclusively breastfeed an infant up until the 6th month (29). Maasai women typically gain around 11% of their weight while pregnant while the US and Europe gain around

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4 TBAs: Traditional Birth Attendants, who aid and advise women during pregnancy
15-25% during pregnancy. One concern of diet restriction is giving birth to an infant with LBW (low birth weight), predisposing that infant to many medical problems including heart disease, lung disease, hypertension, and diabetes (30). However, Maasai infants born with LBW are around 13%, which is not remarkably high compared to the US and Western Europe (27). Although these traditions contradict practices in the US, they have been passed down from previous generations through experience.

**Child Nutrition**

The growth of 2,000 children was observed in 1989, which discovered little wasting in the children, but some stunting. Stunting was seen less in boys indicating possible cultural favoritism towards boys. Appropriate growth was observed in the first year indicating proper breastfeeding techniques; however, stunting was observed after the second year indicating poor nutrition while weaning allowing an increased susceptibility to infection (24).

**Nutrition and AIDS**

Significant findings point to a link between nutrition and the delay of the progression of HIV to AIDS. Poor growth is common in HIV-infected children and has a significant adverse effect on survival, independent of the degree of immune deficiency (31). Research has even suggested that the nutritional status of individuals may reduce the chance of HIV infection, delay the genesis of the disease and death, and decrease the risk of HIV transmission between mothers and offspring before and after birth (32). As stated by Loevinsohn and Gilespie, “failure to maintain nutritional status weakens immunity and increases susceptibility to opportunistic infections, which in turn undermine nutritional status and hasten the onset of full-blown AIDS” (33).

As pastoralists, Vitamin A deficiency was unheard of due to their high consumption of milk (their main form of Vitamin A). However, signs are pointing to an increased prevalence of this deficiency within the Maasai. It can occur during dry seasons and severe drought and is seen in non-pastoralists. Vitamin A deficiency relates to HIV placing those deficient with an increased susceptibility to genital ulcers (26). In view of these findings it is even clearer that a holistic approach is central to prevention, retention, and
reversal of the AIDS epidemic manifested through the link between conventional medicine and the science of nutrition.

CONCLUSION & SUGGESTIONS

This paper uncovers the very colorful culture and nature of the Maasai people. While researching their lifestyle and practices, many differences appear when compared to Western behaviors. These cultural differences must be considered when thinking of education or outreach to the Maasai people.

Pressing topics of potential education to Maasai include:

- Benefits of planting trees for shade, windbreaks, and prevention of drought or flood
- Benefits of planting native plants to prevent soil erosion
- Sanitation concerns with shared water between households and animals
- Proper pesticide use including wearing proper protection
- Reduce the practice of sexual promiscuity resulting in a greater prevalence of contracting HIV
- Promote testing of HIV among women
- Educate Traditional Birth Attendants on the importance of appropriate weight gain during pregnancy and other sanitary birthing practices
- Benefits of exclusive breastfeeding
- Promote the consumption of green and orange vegetables to increase Vitamin A intake

Certain efforts performed by NGOs and other concerned organizations are noted in this paper. However, a further review of case studies focusing on the specified issues would be beneficial in order to understand the success and hardship of aid efforts. Some highlighted projects that would be beneficial include the success and strategy of educating the Maasai about benefits of stricter hygiene and sexual practices, exclusive breastfeeding, proper nutrition, and sustainable environmental practices.

Beyond issues present within the Maasai people, many lessons can be learned from them and their lifestyle. They are rich with traditions and care for their community. When addressing ways to positively affect a culture, it is important to remember that many lessons can be learned from them as well. Hopefully, the information gathered will provide a foundation for further
involvement of the diverse Cal Poly campus to bring positive changes in the health and survival of such a beautiful people as the Maasai.

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32 STUDENT RESEARCH
OPTICAL TWEEZERS CALIBRATION AND BACTERIAL ADHESION

Nakia Wheeler, Student Author
Dr. John Sharpe, Research Advisor

EXECUTIVE SUMMARY

In this project, we will be measuring the forces of the binding of bacteria. We will be working with *Lactobacillus acidophilus NCFM*, *Lactobacillus gallinarum 33199*, *Lactobacillus ruteri 23272*, and *Bifidobacterium*. These bacteria are lactic acid bacteria and are used as probiotics. We also reviewed literature on the bacterial cell wall constituents and the properties of adhesion applicable to these organisms.

INTRODUCTION

The main goal of the project is to measure the force of bacterial adhesion to milk fat globule membranes. This information can help us gain insight into the probiotic properties, or health benefits, of certain bacteria. This work can also aid in understanding biofilm formation properties. The main technique of this project is the application of optical tweezers to biological subjects. Optical tweezers basically consist of an infrared laser beam focused through a high-powered microscope objective lens; the laser can then be used to “trap” particles, or in our case bacteria, and after calibration, use this to determine the force exerted by the trap.

Our optical tweezers system is composed of a 1064 nm laser and a Zeiss Axiovert microscope utilizing an NA1.25 oil immersion objective lens.
BACKGROUND

Optical traps, also known as optical tweezers, were invented about 25 years ago by Arthur Ashkin, the pioneer of laser-based optical trapping. To trap an object, a laser beam must be focused through an oil immersion microscope objective. The tweezers have been used to manipulate and measure objects since their invention, however their use on biological subjects is relatively recent. The full potential of the optical tweezers technology has yet to be reached, resulting in much scientific excitement.

The concept of optical tweezers is based on the principles of optical refraction and momentum conservation. The optical trap of the tweezers is a focused laser beam that is projected onto a particle. As light hits the particle, the refractive properties of matter forces the light to bend inward around the particle. Since the light has momentum and has changed direction, there is a force exerted on the particle. It is this force which pinches the particle and holds it in place. The strength of the trap is determined by the intensity of the light. The goal of the aforementioned calibration is to map a light intensity to the corresponding force exerted on the particle (which is usually measured in piconewtons).

To conduct experiments on bacterial adhesion, a basic understanding of adhesion mechanisms is essential. The bacteria we are using are Lactobacillus acidophilus NCFM, L. gallinarum 33199, L. reuteri 23272, and Bifidobacterium spp. Studies have shown that bacterial adhesion to host cell surfaces is facilitated by hydrophobic/hydrophilic, Lewis acid/base, electrostatic, and van der Waals interactions. Other bacterial adhesion factors (adhesions) that are specifically present in Lactobacillus spp. and Bifidobacterium spp. are the S-layer and the lipoteichoic and teichoic acids.

DESIGN

Figure 1 shows a schematic diagram of the tweezers system while Figure 2 is a photograph of the laboratory set-up. The lab is located in Building 52 in the Dynamical Systems Imaging Laboratory.
EXPERIMENTS

Bacteria
Unfortunately, we have not been able to conduct any experiments on bacteria because we have not received bacterial samples or the Milk Fat Globule Membrane coated spheres from the Dairy Science Department.
Calibration
Using a moving piezoelectric stage, we measured the trap strength by measuring the drag force (also called Stokes drag) on the trapped particle due to moving fluid. By adjusting the stage velocity, we can vary the drag force until the particle just detaches from the trap. The trap force can be calculated from the following equation:

$$\text{Force} = 6\pi \eta v_{\text{max}} r$$

Where $\eta$ is the fluid viscosity (= 0.001 Pa s for water at 22°C), $r$ is the particle radius (we used 0.5 µm radius polystyrene beads), and $v_{\text{max}}$ is the maximum velocity of the stage at which the particle detaches from the optical trap. We explored the trapping strength as a function of the laser power, noting that trap strengths of order 10 pN can be obtained. We also measured the trap strength as a function of distance from the coverslip, showing that strong trapping can only be effective from about 5 to 30 µm from the coverslip. The trap is most effective at a level of 10 µm above the coverslip. This is discussed further under the calibration section.

RESULTS

Research
Due to a lack of samples to work with, I have been focusing on researching the bacteria we plan to use. Topics of research include properties of lactic acid bacteria, probiotics, the gram positive cell wall constituents, and bacterial adhesion.

Lactic acid bacteria
Lactic acid bacteria are phylogenetically diverse, gram positive bacteria that produce lactic acid as a sole or main end product of sugar fermentation. Lactic acid bacteria are non-sporing and generally non-motile. They lack cytochromes and obtain energy by substrate level phosphorylation, rather than by electron transport, ATP synthase, and oxidative phosphorylation. *Lactobacillus* spp. are widely used by the food industry in the production of fermented vegetable products, beverages, sourdough bread, and several meat and dairy products, however some species can also be associated with food spoilage.
Species of the genera *Lactobacillus* are generally recognized as safe (GRAS) due to non-pathogenicity and their long history in the food industry.

**Probiotics**

The large intestine of humans and animals contains a complex, but balanced microbiota, which normally prevent infection and have a positive affect on nutrition. This microbial balance can be upset by stress, antibiotic therapy, or an abrupt change in diet, leading to host susceptibility to disease and a decrease in food use efficiency. Probiotics are the oral administration of living microorganisms and have the potential to reestablish the natural balance and return the host to normal health and nutrition. Probiotic organisms have been proven to provide health benefits to animals such as sheep and cattle, however there is evidence that certain probiotic microorganisms may also offer considerable benefits to humans as well. Some of these potential benefits include anticarcinogenic activity, control of intestinal pathogens, reduction of serum cholesterol concentration, and the improvement of lactose use in individuals who are lactose intolerant. The development of probiotics for humans is still in the early stages, but exhibits a promising future.

**Cell wall constituents**

The gram positive cell wall consists of a single peptidoglycan, also called murein, layer that is 20 to 80 nm thick and lies outside of the plasma membrane. Peptidoglycan is a polymer containing two sugar derivatives and several different amino acids. Usually, gram positive cell walls also contain large amounts of teichoic acids (not present in gram negative bacteria), which are polymers of phosphate, glycerol or ribitol, and a side chain R, which represents glucose, an amino acid, or some other molecule. The teichoic acids can either be covalently bonded to the peptidoglycan, or to the plasma membrane lipids, in which case they are called lipoteichoic acids. Teichoic acids extend out towards the surface of the peptidoglycan and because they have a negative charge, contribute to the negative charge of the gram positive cell wall.

Many gram negative and gram positive bacteria, including all species we are studying, possess an S-layer on their surface. The S-layer is formed by an intrinsic self-assembly process and is a regularly-structured, lattice pattern of
protein, glycoprotein, or both, exhibiting oblique, square, or hexagonal symmetry. S-layers are highly porous, with pores of identical size and morphology that cover up to 70% of the S-layer surface area.

**Bacterial adhesion**

Studies have shown that bacterial adhesion to host cell surfaces is facilitated by hydrophobic/hydrophilic, Lewis acid/base, electrostatic, and van der Waals interactions. Bacterial adhesion factors (adhesions) that are present in *Lactobacillus* spp. and *Bifidobacterium* spp. are the S-layer and the lipoteichoic and teichoic acids.

Both hydrophobicity and electric charge are consequences of the chemical properties of the bacterial cell surface. The S-Layer proteins convey hydrophobicity to the *Lactobacillus* spp. cell surface, while the teichoic and lipoteichoic acids give the surface a negative charge. A specific feature of *Lactobacillus* spp. S-layers is the higher content of hydrophobic amino acids and amino acid residues with hydroxyl groups, than S-layers of other organisms.

The exact function of the S-layer is unknown, however it does play a role in bacterial adhesion. It is hypothesized that the method of mediating adhesion is through hydrophobicity. Removal of the S-layer proteins by LiCl extraction significantly reduces the adhesiveness of the bacteria. Also, experimental approaches to apply the binding receptor sites of the S-layer protein to other non-S-layer possessing bacteria can be demonstrated. Non-adhesive lactic acid bacteria can be turned into adhesive by inducing the expression of a different species’ S-Layer protein or its receptor binding region.

Previously, the tweezers were applied directly to the bacterium. To perform a much more exact and reliable force calibration, a “handle” needs to be attached to one end of the bacterium. A possible handle would consist of a small polystyrene sphere coated with streptavidin and adhered to biotinylated bacteria. Also, the milk fat globule membrane-coated spheres will be adhered to the coverslip. These two adjustments will allow the measurements obtained to be more accurate. However, the Dairy Science Dept. is having trouble functionalizing the bacteria to adhere by any method.
Calibration

Using the Stokes Drag method described above, I measured the force exerted on the trapped particle as it relates to laser power and found they had a linear relationship, as shown in Figure 3.

![Force Exerted on Particle vs. Laser Power](image)

Figure 3: Measured force on a trapped 1 µm diameter particle as a function of laser power.

I measured the trap strength as a function of the distance above the coverslip and found that trapping can only be achieved at a distance of about 5 to 30 µm above the coverslip, with maximum strength at 10µm above the coverslip.

![Trap Strength vs Distance above Coverslip](image)

Figure 4: Trap strength as a function of distance above coverslip.
CONCLUSION

The research conducted on the bacteria did not produce the exact results desired. I was really hoping to find information about the exact binding mechanisms of the bacteria we were studying, but had to settle on a general approach due to lack of experimentation and research conducted on our specific bacteria. Using Stokes Drag equation, we can calculate the force exerted on a trapped particle and therefore measure the force of bacterial adhesion. All trapping will need to be conducted at a level of 10µm above the coverslip to achieve maximum force. When we finally receive the bacterial cultures that have been functionalized to attach to a “handle” and the milk fat globule membrane-coated spheres, we can begin to collect data on the bacterial force of adhesion to the milk fat globule membrane.

There is one other issue that Dr. Sharpe and I recently discovered. When a small particle in the laser trap, such as the bacteria we ant to use, is advanced toward a large particle, like the 10µm spheres we planned on coating with the MFGM membrane, there are fluctuations in the trap strength. Two possible solutions would be to: 1) calculate the fluctuations and consider them in our adhesion measurements, or 2) we may be able to avoid the fluctuation phenomena by using 1µm or maybe even 5µm beads to coat with the MFGM membrane.

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Rafael Jimenez-Flores, Cal Poly Dairy Science Department
REFERENCES


OPTICAL LOW COHERENCE REFLECTOMETRY APPLICATIONS TO MEAT TENDERNESS TESTING

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EXECUTIVE SUMMARY

The goal of this research project is to develop an optical low coherence reflectometry (OLCR) system for use in testing meat tenderness. This system will use a precision reflectometer that sends out infrared light to a sample and collects the reflections from the outer layers of the meat to plot a structural representation of the sample in a reflectivity-over-distance measurement. Tenderness is correlated to the relative densities of proteins and connective tissues in the meat, which this technique may be able to image. In the winter of 2007, a system was constructed for testing purposes. In the spring of 2007, testing and data analysis procedures were developed and tests were run on a group of meat samples of varying tenderness to see if correlations could be established between results from OLCR testing and shear force testing. The results show preliminary relationships between tenderness and beam attenuation into the meat samples. Future research is required to have a statistically significant experiment. Modifications to the testing procedure and data analysis techniques are required to establish better correlations.
INTRODUCTION

The most effective current method of measuring meat tenderness involves shear force testing. This testing requires the meat to be cored, cooked, and then cut with a blade of specified dullness. The force that is required to shear the meat is to be measured. With this process, it can be determined how tender the meat is, which is correlated to the ease with which it can be chewed and how palatable it will be. Figure 1 shows a picture of a set of New York Strip steaks being cooked in preparation for measurement of meat tenderness using established techniques. Figure 2 shows a picture of several steaks that have been cooked to specification and are ready for sheer force testing. Figure 3 shows a picture of the shear force instrument that is the present standard for measuring meat tenderness.

Meat tenderness testing is very important to the meat industry, as people are willing to spend more money on meat that is tender versus not tender. Shear force testing, though accurate, is time consuming, damaging to the meat, and reduces the total amount of meat available for sale.
The purpose of this research project is to investigate the application of a technique known as OLCR as an effective and noninvasive means of determining the tenderness of meat. Optical low coherence reflectometry is a measurement method that studies the interference patterns of reflected waves
compared to reference reflections in order to determine the reflectivity characteristics of the sample under test. This project arose from a search for a better way to test the tenderness of meat by Professor John Beckett of the Cal Poly Agriculture Department and the search for applications of a reflectometry process by Professor Dennis Derickson of the Electrical Engineering Department. This proposed solution will correlate the reflection pattern of a sample of meat to its tenderness.

The first phase of the project was to assemble a measurement system capable of measuring the reflectivity versus distance into beef steak samples. In order to accomplish this, a reflectometry system needed to be assembled for meat tenderness analysis. An Agilent 8504B Precision Reflectometer located the Electrical Engineering Department’s Photonics lab was used as the measurement engine in the study. This instrument was donated to the EE department by Agilent Technologies. The 8504B is capable of measuring reflectivity as a function of distance with 15 micron (in air) resolution and 80 dB of round trip path loss in the sample. A custom optical interface had to be developed in order to couple the probing light beam to the sample under test. A lensing system was assembled for the reflectometer using a Graded Index (GRIN) lens. A computer to instrument control interface was designed using the LabView programming environment in order to automate the measurement. Baseline measurement performance for the measurement samples was then obtained.

The second phase of the project was to compare measurements using the reflectometry system to measurements made by the traditional cook and sheer method. The optical testing process was refined and a group of meat samples was tested and the data processed. The next section of this report will present a description of the factors that determine the tenderness of meat and provide a more detailed overview of the reflectometry process used in the experiment. Finally, the testing phase of the project will be described, the results will be presented, and suggestions will be made for future measurements to assess correlation of the two measurement methods.
BACKGROUND

Cuts of meat are cross-sections of a cow’s skeletal muscle. Skeletal muscle is one of three types of muscle that cows and other animals have. Most common muscles, such as the biceps or hamstring, are skeletal muscles. Skeletal muscles are long, narrow tissues composed of many cells running the length of any given muscle. These cells, also known as muscle fibers, are organized into small bundles known as fascicles. These bundles are illustrated in Figure 4. Fascicles are the smallest physical grouping of muscle cells. A bundle of fascicles composes the muscle as a whole. In the macroscopic structure of a muscle, there exists a large number of fascicles, each surrounded by a layer of connective tissue. Connective tissue forms a significant part of the muscle structure and joins in with surrounding muscle cells and fascicles by adipose tissue, which is primarily fat and blood vessels.

Structure of a Skeletal Muscle

![Diagram of a skeletal muscle](image)

Figure 4: An illustration of a skeletal muscle.

Studies have shown that higher concentrations of proteins and connective tissues can contribute to less tender meat. Further testing may be able to show if this relation is true and if it can be found using the reflectometry technique of this project.

A noninvasive method of testing meat tenderness that exists currently is one that correlates the color of meat at a specified amount of time post
mortem and exposure to air to tenderness. A reasonable relation between the color and tenderness is found with this technique. However, it is not as reliable as shear force testing and it would be very desirable for a more reliable noninvasive technique to be developed. Because of this, a multitude of other methods of testing meat tenderness have been and are being explored. However, very few of them show any promise, which is where the technique of OLCR comes in.

The backbone of the OLCR technique used in this project is the Agilent 8504B Precision Reflectometer. Its operation is based on a Michelson Interferometer in which a beam of light is split with part of it going to a fixed mirror and the other to a moving mirror. After the beams are reflected back, they are recombined and the beam from the fixed mirror is analyzed with respect to that of the moving mirror using interference pattern analysis. Figure 5 shows the block diagram of the reflectometry system that was used.

![Figure 5](image_url)

Figure 5: The block diagram of the optical low coherence reflectometry system used for the reflectivity versus distance measurement. Optical interference at the detector occurs when the spacing from the coupler to the meat sample equals the spacing from the coupler to the reference mirror. The wide spectral width of the source makes the interference pattern quickly fade away when two paths differ by more than 15 microns.

A wavelength division multiplexer selects either the 1550 nanometer or 1300 nanometer wavelength infrared LED light source and sends it to the coupler. The coupler splits this light and sends half of it to the reference cable and the other to the test cable. The test cable comes out of the machine and
connects to a lens network. The length of the reference cable is set so that it is equal to the length of the test cable plus the lens network. When the distance from the coupler to a reflection in the meat sample is equal to the distance between the coupler and the reference mirror, an interference signal appears in the detector. When these two distances are more than 15 microns apart, the interference signal vanishes. This 15 micron distance resolution is controlled by the spectral width of the optical signal emitted by the LED source. Reference 1 provides a detailed description of the instrument’s operation.

A lens interface to the sample was designed as part of the project. Figure 6 shows that the assembly consists of a pigtail ferrule feeding a GRIN lens in a lens tube.

![Diagram](image)

**Figure 6:** The optical assembly that was used to couple light from the 8504B measurement instrument into the meat sample under test. The fiber ferrule terminates the fiber with an 8 degree cleave angle and an antireflection (AR) coating. The cleave and the AR coating reduce the residual reflectivity signal back into the instrument. A 0.23 pitch AR coated GRIN lens was then used to produce a converging beam into the sample. The ferrule to GRIN lens spacing was adjusted to achieve the correct convergence angle of the beam for this measurement. Using Gaussian beam analysis theory, the converging beam was designed to have a working distance of about 3 mm near its minimum beam waist. The diameter of the beam was about 20 micron at the beam waist.

Figure 7 shows a picture of the measurement system that was assembled in the project. Figure 8 shows a close up of a sample being measured.

**DESIGN**

The original budget for the project was $5000 ($3800 of that going towards purchasing parts). As can be seen in Figure 6, the set-up consists of the reflectometer, lens assembly, and computer interface. The reflectometer itself costs $50,000; however, this device was already in the Electrical Engineer-
Figure 7: The Optical Coherence Tomography test setup. The Agilent 8504 instrument at the top of the picture provides the reflectivity-versus-distance measurement. The XYZ stage and the imaging lens are shown above a meat sample at the bottom of the picture.

Figure 8: A close up of the GRaded INdex (GRIN) lens assembly that was used to measure the reflectivity versus distance into the meat sample. The average measurement depth of penetration was about 1.2 mm assuming an index of refraction of 1.5.

Phases one and two of the project occurred in the winter quarter of 2007 and the third phase in spring of 2007. In this first phase of the project, the computer interface was programmed so that a data trace could be taken from the device and sent to the computer for analysis. To present the plot, the points are exported to Excel for compiling and analysis. Coding to analyze the plots was not added until later. Getting familiar with the LabView graphical programming environment, developing the code, and testing it took three weeks. During this time, work was also being done on the second phase of the project and continued through the end of the quarter. The second phase of the project entailed assembling the mechanical parts of the system, including the lens network, imaging station, and fiber optic cables. An x-y-z posi-
tioning system and a mounting board were purchased ($906) for holding the lens system. A Grin lens was decided upon for ease of use and the ability to modify the focusing distance by changing the distance between the ferrule and lens. The entire lens system cost $132. The lens parts were ordered in the middle of the quarter but took several weeks to be obtained. In order to get the reference cable the same length as the test cable plus the lens system, all of the parts were measured and it was decided to splice the needed length of fiber optic cable to the lens system. Splicing a cable requires a procedure known as fusion splicing. Each of the cables were to be cut back and stripped so that only the thin fiber was exposed and then sheared to give an even surface on the ends of either fiber for splicing. The splicing was then done with a fusion splicer that used automated aligning procedures to exactly align the fibers, pre-fusion electrical pulses to blow off dust and clean the fibers, and finally high voltage to melt the fibers and fuse them together. The fusion splicer estimated the finished splice loss at 0.12 decibels. Once the fiber connected to the pigtailed ferrule was fused to the test cable, the ferrule was inserted into the lens tube with the Grin lens (as seen in Figure 2) and the lens system was ready for testing. Being in the spring, the testing phase of the project began. Another LabView program was coded so that the plots in Excel could be imported into LabView for analysis. Also, during this phase of the project, tests were performed on meat samples and this will be discussed in the methods section of the report.

METHODS

Different tests were performed on the lens assembly to ensure functionality before scanning. First, an infrared detector card was used to see if any light was coming out. When the infrared light coming from the lens system hit the card, it lit up and was visible. The next test performed was with an optical power meter that works by measuring the power generated from a small InGaAs photodetector. Before the fuse, 21 W of power was recorded coming from the fiber and after the fuse, 20 W of power was detected coming out of the pigtailed ferrule. In order to calibrate and fine tune the focusing distance between the lens and sample, several sweeps were performed until the reflec-
tivity of the sample could be maximized when the sample was a specified distance away. Figures 9 and 10 are examples of plots that were generated from this test.

Figure 9: (top) An example reflectivity measurement for a tender meat sample.
Figure 10: (bottom) An example of the reflectivity versus distance from a meat sample that was considered not to be tender.
For the testing phase of the project, ten meat samples of varying tenderness were obtained from the Cal Poly Agriculture Department. The following cuts were in the test group: 2 top sirloin, 3 eye of the round, 4 New York strip, and 1 bottom round. First, they were analyzed with the OLCR testing system in the EE Photonics Lab and then sent back to the Agriculture Department to obtain shear force testing results. When being tested by the OLCR system, 5 to 8 traces were taken from each piece of meat at different points. At each point, the scanning range and point were selected to maximize the first reflection peak and display most of the region of reflection as seen in Figures 9 and 10. Each point had sixty-four data traces averaged to eliminate nonrecurring reflections and noise.

The task was then to identify key features of the reflectometry trace that might correlate to meat tenderness. A series of different analysis techniques were performed on the data traces, but the only ones that showed real promise were the penetration depth of the beam into the meat that could be imaged and the decay slope of the reflections due to the attenuation of the beam into the meat. These two also offer similar trend lines as they are measuring related features and the results are discussed in the results section.

RESULTS

All of the plots generated in the testing phase of the project were analyzed in Excel and LabView to search for correlations with the tenderness testing results from shear force testing and reasonable correlations were found with penetration depth and decay slope. Figures 11 and 12 show these relationships. From mid to high tenderness values, there is a correlation between tenderness and both penetration depth and decay slope. In other words, tender samples have a shallower penetration depth for the 1.3m infrared light. This trend did not hold for the samples that were the least tender. It seems after a point, penetration depth maximizes and meat being less tender will actually decrease the penetration depth of the beam. We are as of yet uncertain what could be causing this. As for why penetration depth is affected by tenderness, it is known that the main structures in meat are proteins and different fibers which contribute to tenderness. Considerable work is left in making a
more sound judgment on the correlation of reflectometry measurements to meat tenderness.

Figure 11: Here the slope of the reflectometry measurement in dB/nm is compared to the classical meat tenderness measurement on the horizontal axis. The horizontal tenderness access is in units of kg-1. This means that a very tender sample is to the right and less tender is to the left.

Figure 12: In this assessment, the depth of penetration into the sample is compared to the tenderness of the sample.
CONCLUSIONS

There are several factors related to tenderness that can be addressed with the reflectometry technique. The most promising factors in terms of determining the tenderness of meat are connective tissue and protein densities. The more connective tissue present in the muscle and the denser the proteins in the myofibrils, the less tender meat is. These two factors have a significant effect on the reflectometry readings. The decay of the waveforms as imaging is done into the beef is a good indicator of protein and tissue densities. For future research with this device, the data acquisition technique should be more standardized so that all data traces are obtained from the exact same sequences and the results are more meaningful. A much larger sample size is also required to further examine correlations between the present standard and this proposed measurement procedure. Also, a senior project is underway that will add automated actuators to the x-y-z positioning system so that a sample may be imaged at several positions and by combining the data from several positions a three-dimensional image of the beef can be created. With future progress, OLCR may develop into an effective means of determining meat tenderness that can be used for commercial implementation.

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REFERENCES


LIGHT TRAP MANIPULATION AND ITS POTENTIAL USE IN QUANTUM COMPUTING

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Dr. Katharina Gillen, Research Advisor

EXECUTIVE SUMMARY

During winter quarter 2007, the light polarization dependence of light traps used in quantum computing was researched. Throughout the quarter, a Mathematica program that simulates the trapping potential of light traps was modified; it now takes into account the polarization of light used, as well as the internal state of the atoms used in the light traps. The goal for the next quarter, spring 2007, was to use the program that was generated to simulate the trapping potentials of traps of varying parameters. This research was conducted to deduce whether there is any possible way to implement the light polarization dependence of light traps in quantum computing. More specifically, the intent was to investigate potential ways to create a two-qubit gate using the light polarization dependence of the light traps.
INTRODUCTION

Last quarter, a Mathematica program was generated to simulate the trapping potential of light polarization-dependent light traps used for trapping atoms for quantum computing. The program was tested by using it to calculate the trapping potential of a basic lattice with known trapping potential; it attained the correct result. This research is a continuation of Professor Gillen’s doctoral research, which explores the use of two-dimensional light traps as a basis for quantum computing. The goal of this research is to use the Mathematica program generated to simulate light traps of varying parameters to attempt the construction of the holy grail of quantum computing: a two-qubit gate.

BACKGROUND

Before the quest to research the possibility of a two-qubit gate was begun, there was a significant amount of research involved essential to understanding the theory behind quantum computing. First, a qubit is similar to a bit of a conventional computer in the respect that it is the smallest functional part of a quantum computer. In conventional computers, the bits can be linked to form multiple bit gates, which allow for multiple inputs and outputs into a calculation. In quantum computing, multiple bit gates have the same function: they allow for multiple inputs and outputs into and out of a calculation. Single qubit gates have been made; however, multiple qubit gates, or more specifically, two-qubit gates, have not been created. Two-qubit gates are sought after because they would allow for a quantum computing system to function at its full potential.

A qubit is the abbreviation of “quantum mechanical bit” and includes any quantum mechanical particle, such as a photon, an electron, or an atom, that can be used as a basis for quantum computing. However, instead of being initialized strictly to a state of one or zero as a standard bit is, a qubit can be initialized to any combination of both one and zero, as stated by the principle of superposition.

Using the principle of superposition in conjunction with the principle of entanglement, it may be possible to create a two-qubit. Entanglement is a mysterious property of quantum mechanical particles in which they can link
their internal states through various particle interactions. After the two particles become entangled, they can be separated an infinitely large distance. If the internal state of one particle changes, the internal state of the other will change as well [4]. This effect may allow us to link two atoms in the quantum computing system, enabling us to form a two-qubit.

Another important concept to this research is light polarization. Light polarization is the pattern that the electromagnetic field lines in a light wave trace out as the light wave propagates. The electromagnetic field vectors of light can form three distinct patterns while propagating: linear, circular, and elliptical. The electromagnetic field vectors in linearly polarized light simply move up and down as the light travels through spaces, whereas the electromagnetic field vectors of circularly-polarized light rotate as the light wave travels through space. The electromagnetic field vectors of elliptically-polarized light will rotate while propagating; one of the vectors will be shorter than the other, resulting in an elliptical cross section. This phenomenon is being used in the light traps to determine whether there is a way to use the polarization of light to manipulate the light traps in such a way as to create two-qubit quantum.

There are three light traps that are to be manipulated using the polarization of the lasers used in the traps: a basic two-dimensional lattice, a counter-propagating lattice, and a three-mode lattice (all depicted in Figure 1). Each consists of the same basic set-up of laser incident from different directions. However, the three-mode lattice has an extra laser of varying power coming in from one direction. The counter-propagating lattice is distinctive because it has two of its lasers coming in from opposite directions rather than the same direction. Using these traps, atoms can be contained in specific locations. Next, using lasers from above, the atoms can be initialized, read from, and written to.

The developments from last quarter gave us the ability to manipulate the lattices using the light polarization of the lasers used in the lattices. Using laser light polarization in conjunction with other parameters in the light traps, it may be possible to controllably bring two atoms together with the intention of causing entanglement within them in order to a create two-qubit gate.
Using lattices of varying parameters, there is the potential to create an array of qubits and two-qubits that may be manipulated in such a way that they can be used in an analogous manner to a conventional computer.

**THEORY**

Atoms of specific internal states will respond differently to different polarizations of light, and a light polarization that has an affect on one atom may not affect another atom at all [5,6]. This phenomenon would allow atoms of different internal states in their respective traps to be brought relatively close to one another, allowing the atoms to become entangled without risking potential escape from their respective wells. Using this in conjunction with the idea that the lattice can be manipulated by changing various parameters of the light trap, two separate light traps of different polarizations could be brought close enough together to allow the atoms contained in said traps to entangle and form a two-qubit quantum.
METHODS

The calculations for trapping potential are very complex, so they were solved using a math program called Mathematica. During Professor Gillen's doctoral research, she wrote a code that calculates the trapping potential for an atom trapped in lattice composed of linearly-polarized light [1]. This term is called the scalar trapping potential and it is displayed in equation 1.1[7].

\[
U(r) = \frac{2}{3} \frac{\hbar \Gamma}{8} \frac{E(r)}{\Delta E_{sat}}^2
\]

(1.1)

During winter quarter 2007, the vector trapping potential term was added, equation 1.2, [2] to the original Mathematica code, resulting in equation 1.3 [1, 2].

\[
U(r) = g_{nsc}(L, S, J, i, F)m_f \frac{2}{3} \frac{\hbar \Gamma}{8} \frac{\text{Re}[E_0^*(r)] \times \text{Im}[E_0(r)]}{\Delta (E_{0, sat})^2}
\]

(1.2)

\[
U(r) = g_{nsc}(L, S, J, i, F)m_f \frac{2}{3} \frac{\hbar \Gamma}{8} \frac{\text{Re}[E_0^*(r)] \times \text{Im}[E_0(r)]}{\Delta (E_{0, sat})^2} + g_{nsc}(L, S, J, i, F)m_f \frac{2}{3} \frac{\hbar \Gamma}{8} \frac{\text{Re}[E_0^*(r)] \times \text{Im}[E_0(r)]}{\Delta (E_{0, sat})^2}
\]

(1.3)

With this added term, the Mathematica code now takes into account the polarization the light used to trap it, as well as the specific internal state of the atom. After developing the program, it was tested by calculating the trapping potential of a basic two-dimensional lattice with known polarization dependence and attained the correct results [3].

Then, during spring quarter 2007, the code was modified again such that the scalar potential equation also takes into account the polarization of light. This effect is often falsely ignored because it is quite small compared to the other terms and has minimal effects. Once it was discovered that there were terms missing, they were added to the program. The scalar equation, 1.1, changes to equation 1.4 after adding the polarization terms that are generally ignored. [7].

\[
U(r)_{\text{Scalarpotential}} = \frac{1}{3} \frac{\hbar \Gamma}{8} \frac{\Delta_{z,F}}{\Delta_{v,F}} E_{sat}^2 \left[ |E_{\sigma,-}(r)|^2 \cdot (2 + g_f m_f) + |E_{\sigma,-}(r)|^2 \cdot (2 - g_f m_f) \right] + ... \]

\[
\frac{1}{3} \frac{\hbar \Gamma}{8} \frac{\Delta_{z,F}}{\Delta_{v,F}} E_{sat}^2 \left[ |E_{\sigma,-}(r)|^2 \cdot (1 - g_f m_f) + |E_{\sigma,-}(r)|^2 \cdot (1 + g_f m_f) \right]
\]

(1.4)
With this term added, the code fully takes into account the polarization of light and forms a very accurate portrayal of the trapping potential of the light traps.

RESULTS
The result of the research this quarter was the discovery that the three main ideas for creating a two-qubit have fundamental flaws and will not work. Each of the three lattices were tested spring quarter 2007 by varying specific parameters of the light traps in ways that were thought to be conducive to the formation of a two-qubit gate.

Counter Propagating Lattice
The basic shape of the counter-propagating lattice looked promising for trapping atoms because it had well-defined wells. However, when an attempt to manipulate the lattice using its polarization dependence was made, nothing occurred because the areas where the atoms were supposed to be trapped had no electric field. This meant that the atoms could not be moved around.

Basic Lattice
The basic lattice had the desired polarization effects. The lattices can be manipulated and also moved by changing the two relative phases. This would allow two atoms to be brought together and cause entanglement between them. However, the optical trap does not trap atoms very well. The ridges where atoms would be trapped only trap atoms in two dimensions, which means that they can fall out in the third dimension. Since the atom can fall

Figure 3. This figure depicts trapping potential of the counter-propagating lattice. Left is mf=1 and at right is mf = +1. This shows that an atom cannot be moved using this effect.
out, this trap is not suitable for forming a two-qubit, even though the desired polarization effects were attained.

![Figure 4](image)

Figure 4. This figure depicts the motion of the trapping potential along the z-axes due to changing the angle of two waves incident from perpendicular directions in the basic two-dimensional lattice. It also depicts the lack of three-dimensional trapping at the top of the ridges.

**Third Mode Power**

Slowly adding in a third laser along the z-axis allowed a ridge to decrease out of the middle of the light trap in the three-mode lattice. Using this ridge, it may be possible to trap atoms in two separate wells and then bring them together by increasing the power of the third laser. Once the atoms meet, it may be possible to entangle and then separate them forming a two-qubit gate. This trap had the desired polarization effects, but it had the same problem as the two-dimensional lattice in that it does not provide three-dimensional trapping. This trap is also not suitable for forming a two-qubit gate.

![Figure 5](image)

Figure 5. This figure depicts the dropping of the ridge in the middle of energy well as the power of the third mode increases.
CONCLUSION

In the research spring quarter 2007, the Mathematica code was further developed from the last quarter so that it now takes into account the polarization of the lasers used in the light traps. Once this was completed, an accurate code that worked correctly was available. Using this code, the parameters of the light traps were modified and three possible ways to create two-qubit, the overall goal of this research, were found. However, the three lattices used to create the two-qubit gates ended up being fundamentally flawed: either they do not provide enough trapping or they do not have the desired polarization effect.

This research was originally presented at the Department of Atomic Molecular and Optical Physics conference in Calgary, Alberta and after discussion, my peers agreed that the results did indeed make sense. The three potential ways that a two-qubit gate could be created were investigated; however, there are still many more possible ways that need to be researched. Currently, ideas for continuing this research are to perform the same simulations, but with an external electromagnetic field added in to determine how the external electric field may be used to manipulate the lattice. Professor Gillen also suggested that the code be modified so that it uses a different type of laser, which may affect the traps in other ways.

REFERENCES

A HOME DEVICE FOR VESTIBULAR STIMULATION

David W. Dyk, Student Author
Partnered with Victoria Drake, Patrick Wallis, and Gregg Baker
Dr. Brian P. Self, Research Advisor

EXECUTIVE SUMMARY

The goal of this project, which was presented to the team by Kevin Maher (President of Advanced Therapeutic devices), was to develop a product prototype for safe, vestibular stimulation for children with developmental disabilities. Vestibular stimulation is a form of therapy that increases muscle coordination. It works by stimulating the canals and sacs within the inner ear that detect accelerations. The project targeted children from ages two to seven years old, under 48 inches tall, and less than 100 lbs. The production device also sought to differ from stimulation devices found in hospitals in a few respects: it would cost under $5000, reside in a patient’s home, be hand-powered, and be controlled by an average person. The final device needed to support a 200 lb. load at the edge of the structure and adjust for the center of gravities for the range of children.

After sessions of brainstorming, the team produced three workable layouts, only one was adequate. The final setup had a structure of ¼ in. aluminum structural pipe similar to a football field goal. This structure mounted on a single bearing housing and steel shaft. The final design had two bars to mount weights in order to adjust the center of gravity. The prototype, however, used a swinging bar, lock, and a sliding weight. The final prototype had an adjustable footrest and a five-point restraint harness. The final cost and weight was $1700 and no more than 500 lb. The design met all of the requirements and had adequate safety for any child’s needs, but the team thought the design needed significant changes before it became a final product.
INTRODUCTION

This report discusses the results of research, design, and construction of a device for vestibular stimulation. The final results come from one quarter of design and one quarter of building the prototype.

The vestibular stimulation project began with Gregg Baker and Victoria Drake. The two senior design students received this vestibular stimulation project from Kevin Maher, President of Advanced Therapeutic Devices (ATD). He desired a cheap, safe, and reliable system for delivering vestibular stimulation, since children with developmental disabilities have generally shown improvements in areas such as muscle coordination after receiving this sort of treatment. This actual process of vestibular stimulation will be discussed in greater detail later in this report.

Kevin Maher wanted a human-powered, vestibular stimulation device different than others found in hospitals. These different motor-powered versions cost a large sum of money and cannot be easily installed in a person’s home. Maher asked the team to design a more practical, human-powered version that costs less, resides in a person’s home, and provides the same treatment. He imagined the prototype would serve as a starting point for a production product.

This prototype needed to meet these general requirements:

- Provide for the child’s safety
- Have adequate comfort
- Cost under $5000
- Have a fairly simple assembly
- Fit within a common home
- Ship in small, few, low-weight parts
- Require minimal effort to rotate
- Be easily controlled by an average person
- Adjust for a range of children’s sizes
- Produce minimal noise and vibrations
- Rotate about both a vertical and horizontal axis

The chair aimed to accommodate children from ages two to seven years old, up to 100lbs., less than 48 inches tall, and the group assumed the par-
ents would rotate the chair for the children. In addition, Maher required that the prototype sustain a 200 lb. load at the farthest side of the structure. The group set the cost requirement at $5000 since the motorized stimulation devices found in hospitals can cost more than five times that amount. The team also saw through research that the chair needed to rotate in a certain manner to provide adequate stimulation.

I joined the team to assist in the design, manufacturing, and research as part of the Honors Research Program. Patrick Wallis joined the group to provide manufacturing experience and more insight into the design of the vestibular stimulation device. The whole team worked together to design and construct the device that would stimulate a child’s vestibular system.

The following sections of this report follow the basic process of design and testing. The background research into the vestibular system and its stimulation gives essential information on what the device will accomplish. From this research, the group developed many ideas, but decided on a single application. Next, the team finalized the design with estimations of the criteria (cost, forces and moments, weight, dimensions, comfort, and safety). The final structural layout went into prototype production, which went through a short phase of testing. After observing the model device at work, the group found that it satisfied all of the basic requirements, but thought it was too complicated a structure for a production model.

BACKGROUND OF THE VESTIBULAR SYSTEM

In order to gain a better understanding of the design requirements, the team gathered research about the vestibular stimulation process to understand how the vestibular system senses motion during both linear and angular acceleration. This went to help the device achieve the best results. The group learned that the vestibular system gives the sense of all accelerations in addition to the five senses of taste, touch, hearing, smell, and sight. This bodily system sits in the inner ear and has two parts, one for the sense for angular acceleration (or rotation) and another for the sense of linear acceleration.

The first set of organs, the three canals in the inner ear, detects angular acceleration (see Figure 1). The posterior, horizontal, and superior (or ante-
rior) canals belong in three planes oriented at right angles to each other. Thus, each channel approximately corresponds to the three axes of rotation: pitch, yaw, and roll (Coulter). These canals also contain a fluid called endolymph that circulates in these three approximately orthogonal channels (Vilis). The endolymph moves cilia, which lie within a gel-like substance called the cupula (Coulter).

When the body or the head rotates, the endolymph within the canals begins to flow, which pushes the cupula. The cilia, in turn, send signals to the brain when they bend to the side. The brain then interprets these signals as a rotational sense, like the sense when you shake or nod your head. For longer, sustained rotations, the speed of the endolymph eventually catches up with the rotation of the body, and the cilia will not send a signal. This makes a person feel stationary even while it rotates. If the body suddenly stops from rotating in this state, the person feels dizzy because the endolymph rotates and the body does not. The brain actually receives a signal that the body is rotating when it is still in reality (Coulter). Spinning around the end of a baseball bat for a sustained period and walking afterwards is difficult for this reason. All this information tells us that the vestibular stimulation device should have the ability to change velocities quickly to prevent the patient from getting used to long, sustained rotation.

Two sacs, called the utricle and saccule, work in the vestibular system to produce linear acceleration senses, like the sense from falling or leaning. The human body has two sacs in order to provide sense in two planes of motion, one for the horizontal plane and one for the vertical plane (“Equilibrium and Perceptions”). The saccule senses vertical acceleration and the utricle detects horizontal acceleration (Coulter). These sacs also tell the brain the body’s
direction relative to gravity, or in other words, which way is up. The stimulation of each sac happens in a similar way to the semi-circular canals. When a gelatinous substance and ear stones in the sacs move nerves, the nerves become stimulated and send a signal to the brain (Vilis).

So what does this all do for the body? Basically, the vestibular system helps a person know about balance, motion, and body position (Coulter). The two components of the vestibular system help with motor coordination and stimulate muscles to keep posture (“Equilibrium and Perceptions”). Also, the two sets of canals in either ear work together to stimulate eye muscles so a person can focus even while the head rotates. This reflex is called vestibular ocular reflex, or VOR (“Equilibrium and Perceptions”).

The team’s vestibular stimulation device will excite the vestibular system and develop all of these vestibular functions. Some research has shown that this stimulation can help development of many different body functions, one of which is motor coordination. Some therapists have already implemented this sort of stimulation and observed somewhat positive results in some patients’ development (Ardent). Still, the patients needing these devices cannot afford motor-driven versions of their own and must make frequent trips to hospitals for treatment. The vestibular stimulation prototype the team designed can get the same results without the motor, with less cost, and also remain in a patient’s home.

A wide variety of people have shown vestibular dysfunction. An examiner could notice vestibular problems in people with dyslexia, “…schizophrenia, autism, psychosis, behavior disorders, Down’s Syndrome, minor neurological impairment, hyperactivity, communication disorders, adolescent idiopathic scoliosis, multiple sclerosis, cerebral vascular accidents, mental retardation, developmental delay, otitis media, and Parkinson’s disease” (Greg). The final vestibular stimulation prototype aims to help children with these kinds of disorders.

In “Vestibular Stimulation as a Form of Therapy,” Kelly Greg discussed the optimum configuration for a vestibular stimulation device that would help the people with the aforementioned disabilities. She noted a child needs rapid accelerations for high stimulation. If the stimulation system moves slowly and
repetitively, it could actually have an inhibitory effect. In addition, different
directions of rotation excite different canals and the utricle and saccule expe-
rience the most stimulation when upside down. Greg also stated the patient
must experience constant velocity rotation for at least one minute before com-
ing to rest to achieve maximum stimulation. If a constant velocity lasts less
than a minute, the fluid in the semi-circular canals return too quickly to the
resting state. The team kept all these requirements in mind while completing
the design of the prototype.

SUGGESTIONS OF DESIGN

The vestibular stimulation team came up with many ideas on methods of
delivering the therapy. For some ideas, the group built upon the strengths
of Kevin Maher’s prototypes. In other cases, ideas broke away from conven-
tional concepts in order to produce a sufficient solution. In the end, only a
few concepts looked like real possibilities. The more practical concepts are
shown in Figures 2-4.

Each idea had its own problems and advantages. Some, like the “concentric
circle” design in Figure 2, would provide fast rotation, but had inherently dan-
gerous characteristics. Also, some concepts would operate in a sort of unpre-
dictable motion, which would pose a big problem for the controlled stimu-
lation that the problem required. The team also noted the ideas that would
have the most frictional losses and those with a good amount of comfort.

After discussions with Maher,
the group chose the second idea
(Figure 3), a vertically oriented
chair that rotates about a hori-
zontal axis on a rotating base.
This application offered struc-
tural stability, simplicity, com-
fort, and good overall control of
the motion.

Figure 2. The first design concept has two concentric
circles for two axes.
METHODS OF DESIGN

The majority of the team’s design work came from research on components, ideas on application of these components, and calculations. Since this device did not have any predecessors to follow, aside from Kevin Maher’s small prototypes and experience, the group relied on innovation.

A few factors played major roles in detailing the idea. These held the focus of the group during the design:

- Friction within the base
- Variable center of gravity
- Structural loads and moments

For details, such as the size of piping, shaft diameter, and other specifications, Gregg Baker and Victoria Drake performed calculations in order to find more specific external load requirements. They found statistics on loads on the piping, pipe fittings, bearing housing, and base. These calculations helped the project meet its goals. For example, Baker found that the base (with the appropriate structural dimensions) supported a 200 lb. load at the edge of the structure, resisted falling over from the resulting 400 ft-lb moment, and sustained a 75 lb. force 4 ft. above the base.

As research, ideas, and specifics developed, the team updated SolidWorks drawings in order to visualize the prototype’s layout. Once the team built the prototype, it went through a series of tests. In addition, the prototype con-
firmed the center of gravity calculations. Finally, loads at points of interest confirmed the soundness of the structure.

**FINAL DESIGN**

The final design, illustrated in the attached appendix, meets all of the requirements for a successful home vestibular device (please refer to the appendix to clarify the layout of the assemblies mentioned in this section). Some of the highlights of the structure include an adjustable restraint and footrest, an adjustable center of gravity, good safety, light components, and compact design.

The basic support structure follows a sort of field goal shape. This offered the best solution to the frictional problem. With rollers, a person driving the device would exert too much effort, but with a single, central housing, the device rotates freely. The base has 5 four-foot struts mounted to the bearing housing with half-inch bolts. The base also uses 1.5 inch diameter structural aluminum tubing for the support structure, which connects with aluminum pipe fittings pre-drilled for a set screw. The other side of the pipe fitting has drilled holes to lock together with the tubing by a bolt.

The seat needed adjustability, comfort, and rigidity. The chair itself has a plywood back and is supported by T-slot structural members. The plywood provides adequate support while T-slots allow an assembler to easily bracket the entire structure together. The chair has two angled slots with an adjustable shoulder height to accommodate children of different heights and shoulder widths. The restraint system is a five-point harness, which provides excellent safety. The fact that this harness can be found on a few children’s car seats speaks to its security. This five-point harness tightens by a single belt that passes under the seat into a locking mechanism. This allows the seat to secure quickly and with minimal effort, which posed a concern earlier in the design.

The chair sides have 2 four-foot diameter plywood disks mounted on each side of the chair in order to keep the child’s arms from moving outside the chair. They also help a caregiver propel the chair with minimal effort and without safety problems. The high-quality plywood disks have no dangerous gaps, rough edges, or open holes.
The bearing housing is the most critical piece in the design. It supports the 400 ft-lb moment for the two bearings held within it and it allows the entire structure to turn freely. This critical piece holds the bearings and the lathed shaft securely. The bearings themselves sit on the stepped shaft, which attaches to the pipe fitting at the center of the chair’s support structure. The housing has a flange with 10 points of attachment for the base struts and this flange has a weld on one side to attach to the bearing housing. Destruction testing of the weld showed that it exceeded the strength requirements for the structure.

The most difficult task presented to the team was the adjustable center of gravity. To accommodate for all the different positions of the target child, the design specifies T-slots behind and below the chair that span the distance between the two disks. The team originally planned for a person to simply strap added weights to these bars in order to shift the center of gravity in line with the axis of rotation. However, this design characteristic changed after we constructed and tested the actual prototype.

PROTOTYPE CONSTRUCTION AND RESULTS

During the second quarter of this project, the group constructed a prototype to test the final design and to demonstrate that the actual product met the given requirements. The team encountered a few problems, but eventually ended up with a result similar to the original layout.

First, T-slots are relatively simple to put together, but they have a couple major problems. The T-slots ended up being the most expensive component on the structure. Furthermore, the advantage of using T-slots was also their biggest nuisance. T-slots do not require much cutting, welding, or drilling, but they need countless screws and nuts to hold them together. The complex framework posed a tedious task of assembly, even for the team—the actual designers. A user of this chair would have an even harder time trying to assemble it. The extensive T-slot chair frame may be just too convoluted and expensive to suit a production model.

However, the harness succeeded in providing good restraint. It secured some test weights well and even safely held one child during rotation about
The process of making the housing consisted of numerous time-consuming tasks: cutting the base plate, cutting the housing, milling the inside of the housing, and drilling set screw holes. All these extra manufacturing processes increased the cost of the structure. The housing required a large amount of machining because the bearings would not stay in place while the chair rotated. The shaft and tubing structure actually wobbled within the bearing housing, and the bearing itself was slipping out of the sleeve. A set screw hole at the top of the bearing housing and a ridge on the bearing for a set screw to hold it solved the problem. In the end, though, the housing worked very well. The bearings would glide with little frictional loss and the stability issue became almost nonexistent.

While the bearing housing had major issues, the counterbalance tests gave us the greatest insight. The group tested a new idea. One bar could swing to different angles to offset the axis in different directions. Also, a weight mounted on the slider could sit at different distances to change the amount of offset
The final counterbalance idea uses mountable plates of 2.5 lbs. each (see Figure 6). Holes in the disks at different angles would allow the bar to lock in. So, after constructing the prototype, a test showed the best option. Weights in different areas on the chair simulated a child’s weight while the chair rotated during the test, which simulated a child anywhere from 30 to 100 lbs. The weight bars in the original design needed too much weight (a total of 30 lbs.) to have run effectively with a child over 80 lbs. This option obviously did not work well enough to use. The swing bar, on the other hand, was relatively easy to use and worked much more smoothly. It also did not require the constant addition of weights like the counterbalance bars. Instead, only the distance where the weight was mounted needed adjustment. However, this solution had its own problem. One weight could not accommodate both a smaller child and a larger child. With a larger counterbalance (more than 10 lbs.), the weight, even at the setting closest to the pitch axis, would offset a smaller child (less than 50 lbs.) so much that it overcompensated the shifted pitch axis, but a smaller weight did not have enough weight even at the farthest extension to suit the larger children (greater than 85 lbs.).

In the end, the design allowed three 2.5 lb. weights to be added to the adjustable bar, but narrowed the suitable weight range for a child. The structure would no longer accommodate a child above 85 lbs. The team thought this was reasonable since a child this large could not sit comfortably in the chair.
In conclusion, the team would like to change only a couple things about the prototype:

1. Replace the T-slots.
   The chair takes a long enough time to construct without them. The numerous components of the T-slots were the biggest cost for our prototype.

2. Adjust the seat structure.
   Originally, the group did not consider using counterweights. Because of this, the chair ended up being more complex than necessary. In fact, a manufactured chair that mounted between the disks might substitute for our whole chair structure. A manufactured chair would save cost, reduce weight, cut construction time, and increase simplicity of the structure.

CONCLUSION

The final design gives more than adequate vestibular stimulation to children two to seven years old. It also has subassembly parts that weigh less than 40 lbs., so each part can ship easily. The total weight of the system does not exceed 500 lbs. The device’s total estimated cost sits at $1700, but the vast amounts of machining required for each part could increase the cost of labor. The team’s prototype cost $2,600, but that includes parts and test weights that a production model would not use.

The final design also meets all of the requirements set forth earlier. It provides for adequate safety, suits a child’s needs, and provides a workable solution to the center of gravity problem. Despite the success of the prototype, the design should have significant modifications in order to make a reasonable production system.

ACKNOWLEDGMENTS

A big thank you is due to both Dr. Brian Self and Kevin Maher, for their valuable insight and guidance. This project would not have gotten as far as it did without their input.
REFERENCES


APPENDIX
The following pictures illustrate the final design of the vestibular stimulation device prototype. These pictures do not represent changes made while constructing the prototype, such as the swing bar for a counterbalance weight.
RECIPE FOR AN OUTSTANDING HONORS PROGRAM

Jennifer Merriam, Student Author
Dr. Sema Alptekin, Research Advisor

INTRODUCTION

The primary objective of this research was to compare and contrast the practices of Honors Programs throughout the California State University system. From February 14th through February 24th, 2007, an email survey was conducted of all CSU Honors Program directors. The directors were asked questions about their current program offerings, as well as their successes and failures in the past. This data will be used in fundraising efforts and in guiding future program expansion for Cal Poly San Luis Obispo’s Honors Program and will be distributed to other interested directors.

The survey was sent via email to all eighteen honors program directors in the 2006-2007 CSU Honors Consortium and received nine responses. In addition, answers to certain questions were obtained from the programs’ websites. As promised when the survey was distributed, in order to protect program privacy, responses will not be identified by school name in this report, except Cal Poly SLO, which conducted the survey.

The Cal Poly SLO Honors Program sends a very special “thank you” to the directors of each of the following Honors Programs since their timely participation in this survey was crucial for this paper – Bakersfield, Chico, Fresno, Northridge, Cal Poly Pomona, Sacramento, San Bernardino, San Diego, San Francisco and Stanislaus.
NOTES TO THE READER

Responses may be compared to guidelines established by the National Collegiate Honors Council, which can be viewed at:
http://www.nchchonors.org/basic.htm.

In schools that offer a General Education Honors Program in addition to independent honors programs in the majors, the data in this report refers only to the General Education program enrollment.

In a few places, certain features are correlated with program success. For purposes of this report, “success” is defined as diverse opportunities for students, strong retention rates, strong student satisfaction, and a positive image on campus.

This report will be updated as more data is collected, so survey submissions are still welcome from those directors who have not yet replied.

This survey and report were written by Jennifer Merriam, a junior at Cal Poly, San Luis Obispo. For more information, please contact her at jemerria@calpoly.edu. The director of the Honors Program at Cal Poly, San Luis Obispo is Dr. Sema Alptekin, who can be reached at salpteki@calpoly.edu.

ADMINISTRATION

Is the director full-time or part-time?

The vast majority of program directors are half-time. Of those who responded to the survey, one director is full-time and one program has no director at all.

In that case, the Director of Undergraduate Studies is responsible for the program and a part-time directorship is in the planning stages.

Comparing these responses to their corresponding answers later in the survey, the data suggest that director time is correlated with program success. This is not surprising, but neither does it imply causality. Programs with greater resources can afford a full-time director and that director’s focused time and attention in turn contribute to the program’s success. Each school
has to decide how much director time can be justified for the individual program, but it seems clear that if a program wants to expand significantly, director time must expand as well. A program that overextends its human resources will not endure in the long run.

**To whom does the director report?**

Most directors report to the Dean or Associate Dean of Undergraduate Studies. One reports to the Associate Vice Provost for Academic Affairs and only two report directly to the Provost.

The National Collegiate Honors Council (NCHC) advises that the “honors director should report to the chief academic officer of the institution,” usually the Provost. This is clearly not the trend among CSU Honors Programs.

As with director time, the seniority of the office to which the director reports seems to be correlated with program success. This is logical, since the higher up the command chain the director reports, the more likely the Honors Program is to have positive visibility among campus administration and therefore to receive their support. This becomes even more important as programs expand. In order to receive the financial, academic, and administrative support required to sustain a large program, the director must report to an office whose authority is proportional to the program’s size.

**How many support personnel do you have?**

Most programs have at least one full-time administrative assistant and many have a few part-time student assistants as well. Again, this staffing is generally correlated to program size and success. Funding for these positions seems to come primarily from the program budget, although some are funded directly by the University, which makes them subject to budget cuts. Other programs, especially those with more limited financial

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**Having the director report as high up the chain of command as possible, ideally to the Provost, can increase program visibility.**

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**Look for creative and inexpensive ways to fulfill administrative staffing needs, such as utilizing work-study students or offering community service hours or honors course credit.**
resources, find creative ways to staff their offices, such as offering the position to work-study students or splitting a 3/4-time director position into a half-time director and quarter-time assistant director.

Is there a channel for students to have a voice in the program?
All but one of the programs surveyed has some kind of student voice and the one exception is presently undergoing some renovation and will undoubtedly include such a voice in the future. Each program has its own communication channel – from a simple open-door policy with the director to a formal student advisory board – and each program seems content with its solution.

ENROLLMENT

Approximately how many students are in the program?
Honors Programs range in size from 50 to 450 with the majority forming two clusters – one around 50 and one around 350. There is no apparent correlation between program enrollment and program success, student satisfaction, or student social connection. Program size appears to be limited only by resources and interest in most cases, although some programs’ structure necessitates limits. For example, some programs have an “honors track” that allows students to take a set series of honors courses for the first two years to fulfill their general education requirements and this track can only have a certain number of seats per year.

Approximately what fraction of your applicants do you accept?
About half of the programs accept 90-100% of applicants every year, rejecting only those who do not qualify. Other programs limit their enrollment to
a certain number and thus, admit only the top fraction of their applicants (in some cases as little as 10%). These differences may be due, at least in part, to recruiting patterns – actively recruiting only qualified students means that nearly all applicants will be accepted.

There is no apparent correlation between applicant acceptance rates and program success, student satisfaction, or student social connection. In some cases, so many applications are received every year that the program could not realistically support itself if all applicants were accepted. In others, the honors program is an important recruiting tool for the University and thus, students enticed by the Honors Program must be reasonably certain of their admission to the program in order to choose that University.

**What are the admission requirements for freshmen?**

Every Honors Program looks at high school GPA and/or SAT scores (or corresponding ACT scores) to select incoming freshmen. Many also require letters of recommendation, lists of extracurricular activities, or interviews. In some cases, a high SAT score is allowed to override a non-qualifying GPA, and most programs offer an appeals process for students whose scores disqualify them but who feel that they have special circumstances that warrant consideration. The average minimum requirements are a 3.5 GPA and 1130 SAT (on a 1600 scale), although this varies widely.

A common concern in conversations about Honors Programs is where to set the bar – too high and deserving students are excluded, but too low and the program loses its significance. Each program has to tailor its entrance requirements to its particular student population, because a 3.7 high school GPA, for example, would include very few freshmen on some campuses, but could include half of the freshman class on another. Most programs admit less than 5% of the freshman class, although some choose to go as high as 14%.
Can students transfer into the program after their freshman year?
Most programs do admit transfer students, provided the students still need enough general education classes to fulfill the program requirements. The exceptions to this are the programs in which honors students follow a set track for all their general education honors classes, in which case transfer students would have to repeat most of their transferred courses. However, even when transfer students are not allowed to formally join the Honors Program, qualified students are often encouraged to take honors courses for their upper-division course requirements where applicable.

Admission for transfer students is usually based on college GPA, regardless of whether they are transferring from another school or simply choosing to join the Honors Program after one or two years on the same campus. The average required GPA is 3.4 for all transferable college coursework. Most programs reduce the number of required honors courses for transfer students based on the assumption that these students have already completed much of their general education work and would thus have difficulty selecting enough appropriate honors classes if held to the same standards as freshmen.

How many of your students successfully graduate with honors?
Many directors do not have data on this subject, and among those who do, the answers vary widely. One reports “very few,” while others are as high as 90%. One campus has 80% of its students complete their general education requirements in the program, but then only 50-60% stay the final year and complete the capstone project.

Why do students expend the effort to apply to the Honors Program and take honors courses for a few terms, only to drop out of the program before achieving their objectives? Are they dissatisfied with their experience? Are they unable to meet the academic requirements? Are they uncertain of their purpose for being in the program and therefore unmotivated to put forth the extra work? The reasons for declin-
ing enrollment may include these and countless others, and without clear answers, no progress can be made. Therefore, the first step in combating this phenomenon is information. Cal Poly SLO conducted a satisfaction survey of its honors students this year and the primary reason cited for dropping out of the program was a shortage of honors classes. Armed with that data, the program director was able to begin lobbying for increased funding for the program so that more honors classes could be offered.

Granted, a 100% retention rate is unrealistic because some students will reevaluate their priorities or encounter personal challenges, but the Cal Poly study indicates that program drop-outs are preventable in most cases. Tracking program enrollment and student satisfaction can alert directors to the causes of drop-outs, which is the first step in solving the problem. Having both the student and the program invest in the honors experience for the first few years of college, only to abandon the effort part-way through, is like baking a cake, but pulling it out of the oven early. The baking process can be fun and the kitchen will smell good temporarily, but ultimately there will be no cake to eat and the ingredients will have been wasted. Waiting the last few minutes means the difference between a useless pile of half-cooked batter and a delicious cake that can be enjoyed for days to come.

HONORS COURSES

What are the requirements for students to graduate with honors?
Almost all honors programs require a certain GPA (3.3 on average) and a required number of honors classes, mostly in the general education areas, but the nature of these classes varies widely. There seem to be three distinct categories of honors programs:

1. Entirely Honors Contract – Students arrange to get honors credit for a certain number of courses (typically eight) of their choosing by working with their professor to complete an independent project in addition to the normal coursework.

2. Entirely Honors Courses – All students in the program follow a set series of general education courses, covering two years and almost all of
the general education graduation requirements. These courses often follow common themes, are taught by cross-disciplinary teams, allow for more efficient completion of general education requirements, and offer students the chance to become closely acquainted with their fellow honors students. This is not feasible in some schools, especially those that integrate major and general education courses from the beginning, but it has been very successful in the schools that can accommodate it. Indeed, one such program is currently celebrating its 50th anniversary!

3. Combination – Students may utilize an Honors Contract for a few (typically two) of their honors requirements, then must complete the rest with honors courses, typically in the general education fields. A certain number of undergraduate research projects, study abroad or internship experiences, or other special cases can sometimes be used to fulfill honors course requirements. This is the most common model by far.

About one third of the programs also require a senior project, portfolio, a certain number of community service hours, or other requirements in addition to the GPA and honors courses in order to graduate with honors.

How many honors courses are offered per quarter or semester?

How many honors courses are offered per quarter or semester?

Answers to this question range from one to fifteen with the average falling around five. There is a direct correlation between the number of honors courses offered per term and the rate of students successfully graduating with honors. This demonstrates that even with priority registration (discussed later), there is no substitute for offering enough classes for students to realistically fulfill their requirements on time.
Are your honors courses exclusively for honors students or do you allow blended enrollment?

Programs seem to be split approximately 50/50 on this issue. Most of the blended-enrollment classes are mixed in order to reach enrollment targets if they do not fill with honors students alone, but in most cases these open seats are still restricted to students with high GPAs and/or special permission. None of the programs surveyed allows the open seats to be offered to the school population at large.

Is the program two years or four years?

The two programs that have students follow a set track of general education classes are both two-year programs, but all other honors programs appear to last four years.

What makes your honors classes unique from other classes on campus?

Without exception, Honors Programs try to design their classes to be richer, not harder, with expanded intellectual demands. Programs realize that simply adding more work does not ensure greater learning, and that honors courses that are graded more severely than other courses are not conducive to overall academic success. Honors classes are generally designed to bring top-level students together to facilitate deeper discussions and a more global approach to learning. Some programs even take this so far as to forgo textbooks in favor of primary sources, including classical literature and philosophy. Most programs share similar goals for their students in honors classes, including deeper intellectual challenge, more diverse academic experience, and greater personal responsibility as members of the community.

SPECIAL FEATURES

Does the program include leadership training or opportunities?

Most honors programs do not include any required leadership training or opportunities. A few have optional workshops or presentations, or encourage their students to participate in school-sponsored leadership events, but only
Offering leadership opportunities for honors students, especially opportunities that serve the school, can help answer the question, “How does the Honors Program benefit the campus as a whole?”

one of the nine responses indicates a leadership requirement. This program has the entire sophomore class participate in the Student Leadership & Development Office’s Leadership Academy, which includes three kinds of seminars: personal growth, academic growth, and community service.

Discussions with advancement officers indicate that prospective investors are looking for what sets honors students apart from the general student population. Leadership training, even when optional, represents one opportunity for programs to distinguish their students from every other graduate. Leadership is also cross-disciplinary and can be a venue for honors students in different majors to get to know one another, thus providing that elusive social component to the program.

Does the program include any community service?

Most programs do not require community service, although almost all offer students the chance to do it voluntarily. Among those that do require service, the requirement averages about twelve hours per year. In addition, several Honors Programs are linked with the service learning programs on their campuses.

One Honors Program requires twelve hours of community service per year, of which four hours must be service to the program. This is a very creative way to get students more involved in the program and generates 1200 hours of service to the program annually – the equivalent of a full-time position on a nine-month calendar! In the aforementioned Cal Poly student survey, more than one third of students said they had the time and willingness to get more involved in the program, but did not know what opportunities for involvement were available. For programs feeling short on student participation, requiring a few

Community service can bring honors students together, increase student engagement in the program, and increase program visibility on campus.
community service hours to be devoted to the program each year can help students overcome “apathy inertia” and see the opportunities to make a difference in their Honors Program.

Does the program include any undergraduate research opportunities? Most programs do offer some opportunities for optional undergraduate research. About half of these come in the form of a capstone thesis project in the student’s senior year and about half are faculty-directed independent research projects. In some cases, research conducted outside the Honors Program can count as an Honors Contract and thus, earn honors credit. Some research projects, such as those funded by National Science Foundation grants, can also be a source of scholarships for students.

Besides scholarships, what perks or incentives do students receive from participation in the program? Recognition at graduation and on the student’s transcript and diploma are essentially ubiquitous. In addition, 75% of Honors Programs offer priority registration, 58% offer an honors dorm, and 50% offer smaller classes. There are a variety of other perks as well, including free tickets to campus events, special trips around the state, free parking, interdisciplinary instruction and faster completion of general education requirements.
Do you offer special honors academic advising?

All but one program offer honors academic advising, generally in addition to the student’s major advising. In most cases, this honors advisor is an honors professor, although one program has a paid position for a peer mentor to do it. Most directors also have an open-door policy if students have questions. Advising is especially important in programs without a set series of classes and the one program that does not offer advising has had very serious challenges with students not understanding the requirements or choosing their honors courses effectively. On the other end of the spectrum, one program offers honors academic advising, but also helps its students with applications for graduate school, study abroad, national student exchange, internships and professional school.

What attribute of your program is most attractive to freshmen?

For most incoming freshmen, priority registration and a richer academic experience are the key features of the Honors Programs. Access to top-quality professors and a community of like-minded, hard-working students are also important. Finally, scholarships are attractive and participation in an honors program looks good on a resume or transcript, which is something on which incoming freshmen (i.e. graduating high school seniors) are still very focused. Ultimately, however, looking good on a resume or transcript is not enough to keep students engaged in the program over time, so even if this is a key attractor for freshmen, the program must offer other features to encourage long-term student participation.
What is your approximate annual budget?
These figures are difficult to compare because they cover so many different expenses, such as salaries, scholarships, courses, and office costs, in any combination. From any angle, however, there is an extremely wide range of budgets across the CSU Honors System. At the top, a few programs have annual budgets of $250,000 or more, and on the other end, some programs have no regular budget at all. Some schools have endowments to support the entire program, while others have small endowments for scholarship funds. Some directors are paid by their programs, while others are paid by the Office of Undergraduate Studies. Some programs have to fund honors courses out of the program budget, while in other schools, honors courses are funded by the college offering the course. For these reasons, a meaningful comparison is next to impossible, but it is clear that the absence of a stable budget is extremely detrimental (and in some cases, nearly fatal) to a program, whereas a generous, reliable budget facilitates a variety of activities and resources for students, which contributes to the success of the program.

How much of your funding comes from the state and how much comes from private or independent sources?
About 63% of honors programs are entirely state-funded, 25% receive a mix of state and private funds, and 12% are entirely privately funded with all fundraising conducted by the program director.

Who provides your private funding, and are there any limitations on how it can be spent?
Among those who have private funding, all are endowments from philanthropists with connections to the University, usually in exchange for naming rights to the Honors Program. These major endowments range in size, up to $1,000,000, and carry no restrictions on how to spend the money. Some programs also have small endowments for scholarship funds, which can only be used for student scholarships.
How are your honors courses funded?
Exactly half of responding directors have to fund their own honors courses and half have their courses funded by the respective colleges or departments. Fortunately, most of the directors that have to fund the classes themselves do have larger budgets. There is no apparent correlation between funding source and number of honors courses offered or whether the classes are exclusive or blended.

Do you offer scholarships to your students?
Not every Honors Program has a dedicated scholarship fund, but every program surveyed does have some way of offering scholarships to its top applicants. Often, if the Honors Program does not offer scholarships of its own, a “President's Scholars” program (or something of similar title) will offer scholarships from the University directly to the highest-achieving students. Approximately half of the Honors Programs do offer automatic scholarships to all honors students, ranging in value from a $50 book stipend to a grant package worth several thousand dollars per year. All others offer a fixed number of scholarships to a few highly-qualified students per year. There is no apparent correlation between scholarship offerings and the significance of the program in University recruitment or overall student satisfaction. In the Cal Poly student survey, however, many students cited scholarships as one thing that would encourage them to try to remain in the program when they might otherwise drop out.

SOCIAL SCENE

Is there an opportunity for honors students to connect socially? How “close knit” is your honors community?
Every program has some opportunity for social connection among honors students – parties, retreats, BBQs, dances, and even special trips to national parks or theater productions – and almost all have an honors dorm and an honors student lounge. The degree of student participation in these opportunities varies widely and despite these opportunities many students only really
know the other students in their own class or major. Many directors express frustration with this lack of connection, but it is unknown how students feel about it. Perhaps students have other avenues for social interaction, are too busy to attend many events, or, as is the case with program involvement, are unaware of the opportunities.

If a program is dissatisfied with its social connection factor, a robust honors student lounge (described below) can help significantly, as can an honors-specific dorm. Directors can consult with the Honors Club or send an email survey to all the students in the program to determine student interest in events. Often (throughout most universities, not only in the Honors Programs), students have an opinion but will not express it unless asked, so simply opening that dialog with students about what they would like to see happen in the program can lead to remarkable feedback and positive change.

**How would you describe your honors office or student lounge?**

Honors Program offices vary widely, from a single faculty office to a small freestanding building, offering a variety of amenities to students. The most useful of these features seem to be couches and tables for group study, computers with printers, and wireless Internet access. It is also helpful to have the Honors faculty offices located in the same area as the student lounge, but separated by a wall or other barrier. This proximity facilitates communication and relationships between program students and administrators, giving the program a more unified feel while allowing students to use the lounge space without feeling that they are intruding on the office or are being watched.

The data indicate a correlation between the robustness of the student lounge space...
and how “close knit” the program students are. The lounge is one of the ways (and in some cases, the only way) for honors students to meet each other outside of class, so making it an inviting and useful space increases the likelihood that students will actually use it to connect with each other. Non-academic resources, such as TVs, DVD players, refrigerators and popcorn can help encourage the space to become a “hang-out” location and not strictly for homework, which is important in the development of deeper relationships among students. If a program is disappointed in its social outcomes, the honors student lounge is one resource to examine.

HONORS EXPERIENCE

To your knowledge, what is the impression of your Honors Program on campus?

Visibility and image vary widely among Honors Programs, but on average, they are positively perceived among those who know of the program. About 33% of the directors say their programs are not well known on campus and about 20% feel their programs have a neutral or varied reputation. Surprisingly, there is no strong correlation between program reputation and program size, but there does seem to be some correlation between reputation and both retention rates and honors courses offered per term.

What have you found to be the most important contributor to your program’s success?

Directors attribute their programs’ success to a variety of factors with nearly equal frequency – recruiting and scholarships to attract high-end students, support from administrators, high-quality instructors and mutually caring interactions between students, faculty, and the director.

What have you found to be the most challenging roadblock to your program’s success?

Not surprisingly, insufficient funding tops this list, although apathy (from both the students and the campus administration and faculty) comes in a close second. Recruiting qualified applicants is third, with one director not-
ing the frequent discrepancy between a student’s grades and test scores from high school and their actual ability to perform at a college level. Unfortunately, most of these challenges are not easily fixed. Fundraising is challenging for public schools and apathy is a problem around the world.

Some progress can be made, however! When faculty members are resistant to the program, directors can meet with them to try to determine the source of the resistance and see what can be done to address their concerns. If campus administrators are not aware of the program, a student-led public relations group can help create promotional materials and increase program visibility on campus. This type of project could count as an honors course or community service hours. If students seem disinterested in the course material, it may prove worthwhile to communicate with the honors student body about which courses they would like to see the program offer or what they would like to see done differently with the honors courses already offered to make them more interesting.

**What mistakes would you suggest that other programs not repeat?**

The most common responses to this question address neglecting the program’s support network on campus. In addition to ensuring that any outgoing personnel are replaced in a timely manner for a smooth transition, the formation of a dedicated honors committee appears to be critical to the program’s success. This committee should include campus administrators, faculty from different departments, and usually a few students from different majors. Without this cross-disciplinary support and the political and financial power it brings, a program will have tremendous difficulty surviving, let alone thriving. Having this positive engagement in the Honors Program from people in different areas of University life contributes to the program’s positive image on campus. It also facilitates “networking” on behalf of the program, which can be critical in negotiations for funding and faculty release time.
Similarly, one director strongly cautioned against depending on adjunct faculty to run the program because it creates tremendous uncertainty from quarter to quarter about who is going to be available to teach which courses. Also, adjunct funding is one of the first things a campus cuts, so in case of any kind of budget crisis (as is a nearly constant condition in public universities) the Honors Program is left wondering how to find teachers for the following quarter.

Finally, directors advised that programs tailor their requirements to what students can and will reasonably complete. This generally means focusing honors courses in the general education areas and taking care not to add significantly to students' units required for graduation. This is not simply a matter of student laziness, but of student time and financial necessity to graduate on time. The Cal Poly student survey indicated that, if faced with the dilemma of graduating on time or graduating with honors, most students will choose the former. Therefore, programs dissatisfied with their retention rates should look at how many students are able to completely fulfill their honors graduation requirements with general education classes and how many are having to go out of their way to satisfy the program requirements. More smoothly integrating honors courses into students' schedules can help more students remain in the program and successfully graduate with honors.

**How important is the Honors Program in recruiting students to your University?**

The importance of the Honors Program in recruiting students varies from campus to campus, but it plays at least some role in every case. Even when campuses identify themselves as largely “commuter schools,” and thus not very focused on research or other typically “honors” features, the existence of an honors program allows them to recruit local high-achieving students who might otherwise have gone elsewhere for college.
In general, how satisfied are students with their honors experience?
Of the nine responses, five are “very” or “extremely” satisfied, three are “somewhat” satisfied, and one is neutral. Two programs cite the need for more honors classes as a primary reason for their lower satisfaction rating. This relatively high degree of satisfaction across the board is extremely encouraging, and is a tremendous compliment to the program administrators because it means that despite all the challenges of insufficient funding and absent faculty support, the programs are succeeding and students are gleaning a positive benefit from their honors experiences!

CONCLUSION
Overall, despite extremely challenging financial and campus political circumstances in many cases, the CSU Honors System appears to be accomplishing its central objective – to offer intellectual enrichment to top students. Students and directors agree that there are aspects that could be improved, but in the discussion of possible change, the present level of success should never be overlooked. It represents a tremendous accomplishment on the part of program administrators, faculty, and students, all of whom should be congratulated for their dedication and perseverance with limited resources.

The most common challenges facing Honors Programs are a lack of funding and a sense of apathy on the part of the students, faculty and administration. Raising awareness about the program among faculty and administrators can help combat this apathy, as can collecting clear student feedback about what would make them more engaged in the program.

Program admission requirements must be tailored to the individual campus, but most programs choose to admit less than 5% of the freshman class. As students continue in the program, enrollment tends to drop steadily in each class, until the program drop-outs outnumber the program graduates in some cases. This represents a tremendous waste of resources by both the students and the program, so investigating and correcting the causes of drop-outs is one of the most beneficial steps a program can take when looking to expand or improve its offerings.
An honors student lounge, honors dorm, and honors social events can provide venues for students to connect with one another socially. Leadership and community service opportunities can also contribute to this goal, while increasing program visibility on campus and providing students with valuable hands-on experience. Honors distinction on a resume or transcript may attract many freshmen to the program, but there must be deeper motivation for student engagement if students are to remain in the program and care about its success.

There are three main kinds of honors programs – exclusively honors contract, exclusively honors courses, or a combination. Which system is most applicable depends on the school’s existing academic structure and the program’s resources, but in general, students tend to find greater satisfaction in honors courses than in honors contracts. There is a direct correlation between the number of honors courses offered per term and students’ rates of successfully graduating with honors. Even a program with all other beneficial elements in place cannot succeed if its students cannot get the classes they need. Finally, it is vital that these courses accomplish their goals without delaying student graduation.

Although program design varies with each campus’s unique population and needs, there are common ingredients in most programs’ recipes – smaller classes, close faculty contact, and a richer University experience. These are worthy goals, but can be difficult to measure, so it is critical that student feedback (preferably anonymous feedback to encourage honesty) be collected at regular intervals. This feedback must cover two subjects: first, is the program accomplishing its goals; second, do the program administrators and students agree on what those goals should be? When everyone in the program is working toward the same vision, it becomes much easier to utilize resources efficiently and ensure a positive outcome for all involved.
Recipe for an Outstanding Honors Program

Ingredients:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cup honors courses</td>
<td>8 oz. support network</td>
</tr>
<tr>
<td>2 tbsp. social connection</td>
<td>1 cup stable budget</td>
</tr>
<tr>
<td>4 tbsp. administrative personnel</td>
<td>16 oz. student feedback</td>
</tr>
</tbody>
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Directions:

- Review the program’s offerings and student satisfaction ratings.
- Evaluate where there might be room to improve.
- Choose a few key improvements on which to focus first.
- Investigate what is required to make those happen.
- Propose an action plan.
- Execute the plan.
CONTRIBUTING STUDENTS

Ruth Brady graduated from Cal Poly in 2007 with a degree in Nutrition and a minor in Biology. Ruth hopes to work in the public health arena educating people both nationally and internationally so they can live healthier, more nutritious lives. Ruth will enter the Hines VA dietetic internship program just outside of Chicago in the fall of 2008 where she will gain the skills and experience needed to become a registered dietitian.

David “Bert” Copsey is a third-year Mechanical Engineering major interested in designing electric vehicles after graduation.

David Dyk is a junior Mechanical Engineering major who plans on continuing his education by pursuing a Masters degree in Biomedical Engineering.

Jennifer Merriam is a third-year Graphic Communications major specializing in Design Reproduction Technology. Jennifer plans to continue studying graphic design and use it for community outreach and education.

Matthew Schlutz is a fourth-year Electrical Engineering and Communications major. Matthew plans to graduate from Cal Poly in 2009 with a Masters degree.

Alan Tepe is a second-year Mechanical Engineering major concentrating in Mechatronics. Alan plans on pursuing an MBA after graduation and hopes to start his own engineering company.

Nakia Wheeler is a fourth-year Microbiology major with a minor in Women’s Studies. Nakia hopes to attend to medical school and become an obstetrician.
CONTRIBUTING FACULTY AND STAFF

Dr. Sema E. Alptekin is currently the Director of the Honors Program and has been a professor for over 14 years in the Industrial and Manufacturing Engineering Department — she served as Department Chair for 6 of those years. Before coming to Cal Poly, Dr. Alptekin earned a BS and MS in Mechanical Engineering and a PhD in Industrial Engineering from Istanbul Technical University (ITU) then worked at ITU, University of Missouri-Rolla, and General Motors. She recently spent two years as a Visiting Scholar at UC Berkeley's Electrical Engineering and Computer Sciences Department. Her current research interests include applications of soft computing technologies in the design of intelligent systems.

Dr. Dennis Derickson is an Assistant Professor of Electrical Engineering who spent sixteen years working for Agilent Technologies, a test and measurement company that enabled him to explore his interests in optical measurements and interactions with materials. Dr. Derickson and his students plan on using their research to develop a more cost-effective method of determining meat tenderness.

Dr. Katharina Gillen is a cold atom physicist by training and has a long-term interest in quantum computing using atoms trapped in light patterns. Working alongside an undergraduate student who presented research at an international conference in 2007, Dr. Gillen feels the project explores new ideas that could advance the quantum computing field. Moreover, the paper has inspired a theoretical/computational research project currently underway.

Dr. Saeed Niku is a Professor of Mechanical Engineering who has previously completed projects in the area of design and hopes to build a prototype of a robotic hand soon. Currently, Dr. Niku is mentoring two additional groups of students who plan on implementing and testing the fingerspelling hand design for their senior projects and theses.

Dr. Brian Self is an Associate Professor of Mechanical Engineering specializing in Biomedical Engineering. Dr. Self has had an interest in this field since working in the laboratory at Brooks Air Force Base where he became involved in spatial disorientation research and the importance of the vestibular system as it pertains to aviation and its therapeutic benefits in child development. Dr. Self and his team hope to deliver the vestibular project to a family that has a child with special needs and possibly work with Dr. Self’s colleague in Colorado to market the team’s design suggestions.

Dr. John Sharpe is an Associate Professor of Physics whose primary interests include the application of optics to measurement. In the future, Dr. Sharpe plans to continue his research exploring all the factors that affect calculating optical forces.