College of Engineering
& Computational Sciences
Capstone Design@Mines
Trade Fair

MINES™

April 27, 2017

Capstone Design@Mines
College of Engineering and Computational Sciences

COLORADO SCHOOL OF MINES
GOLDEN, COLORADO 80401-1887

A Special Word of Thanks to Our Judges

It is my pleasure to offer a personal welcome to the judges of the Spring 2017 Colorado School of Mines College of Engineering and Computational Sciences Trade Fair. We appreciate your willingness to take time from your normal activities to evaluate our seniors' capstone design projects. The opportunity for our students to get feedback from experienced engineers is invaluable.

Senior design allows our students to demonstrate the engineering knowledge that they have spent four or more years acquiring. We encourage you to spend time with the design teams and to inquire about their projects and their designs. But also ask about their design process, because in the final analysis, capstone design is as much about learning the process of design as it is about creating a design. As these students enter the workforce, it is their ability to use the design thinking methods that they have learned that will serve them most in their careers.

We are proud of our students and their accomplishments and hope you are equally impressed. If you would like to get more involved in our program, we are always in search of more project sponsors. Let us know!

Again, thank you and Happy Judging!

Kevin L. Moore
Dean, College of Engineering
& Computational Sciences

Capstone Design@Mines
College of Engineering & Computational Sciences
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Colorado School of Mines thanks the individuals and families listed below who have provided valuable support to the students presenting today.

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Colorado School of Mines thanks the companies and organizations listed below who have provided valuable support to the students presenting today.

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**Denotes donation of materials, services, or supplies to the program.*

Sponsoring the Program

The Capstone Design@Mines Program relies on the generosity of our program sponsors to fund our intercollegiate competition teams, humanitarian engineering projects, and outfit the Design Laboratory. If you, or your organization, are interested in supporting these elements of the program, please consider making a financial gift through the Mines Foundation or via giving.mines.edu. Make sure to clearly mark your gift for CECS Capstone Design@Mines. Your gift is tax deductible and will make a huge impact on our students.

PROGRAM PARTNERS	Donate $25,000 or greater
Your Funds support the needs of many teams. In addition, partners receive:	An invitation to the beginning-of-semester Project Kickoff event. All Sponsor, Supporter, and Donor benefits.

PROGRAM SPONSORS	Donate $10,000 - $24,999
Your funds support the needs of multiple teams. In addition, sponsors receive:	An invitation to, and recognition at the end-of-semester Trade Fair event. All Supporter and Donor benefits.

PROGRAM SUPPORTERS	Donate $5,000 - $9,999
Your funds support the needs of a single team. In addition, supporters receive:	Recognition on the program's website, and on signage in the Design Lab in the Brown Building Basement All Donor benefits.

PROGRAM DONORS	Donate up to $4,999
Donors receive:	Recognition in the end-of-semester Trade Fair Program and a formal letter of thanks from the Mines Foundation.

Colorado School of Mines thanks the individuals and organizations listed below who have served as clients for the student teams presenting today. Your donation of time, talent, and material support to our students is greatly appreciated.

Adaptive Adventures	*Craig DeMartino*
AirBeSpoke	*Kylen McClintock*
Baker Hughes	*John MacPherson, Hans Uwe Brackel*
Ball Aerospace	*Jake Saur; Tracy Copp*
Boa Technology	
Breckenridge Outdoor Education Center	*Jaime Benthin*
Build Change	*Lizzie Collins*
Burns & McDonnell	*Evan Manning*
City of Golden	*Theresa Worsham; Steve Glueck*
Clear Creek Watershed Foundation	*Dave Holm*
CoorsTek	*Greg Reback*
Creative Technology	*Zach Harvey*
CSM College of Eng & Computational Sciences	*Dr. Kevin Moore*
CSM Electrical Engineering Department	*Dr. Atef Elsherbeni; Dr. Jeff Schowalter*
CSM Mechanical Engineering Department	*Dr. Paulo Tabares; Dr. Angel Abbud-Madrid; Dr. Gregory Jackson; Dr. Robert Amaro; Dr. Brian Thomas*
CSM Mining Engineering Department	*Dr. Nicole Smith;*
CSM Petroleum Engineering Department	*Dr. Alfred Eustes; Dr. Jorge Sampaio*
Division of Energy & Mineral Development, U.S. BIA	*Daniel Kaim; Bobbie Wells*
The ENGINER Design	*Paul Brayford*
Enabling Technologies	*Bobby Luscinski*
Gilpin Emergency Medical Services	*Brandon Daruna*
Hazen Research	*Jesse Reeves*
Kiewit	*Chris Bottoms; Ben Seling*
Kleinfelder	*David Micnhimer*
The Invictus Initiative	*Cody Clickner*
Metro Wastewater Reclamation District	*Jim McQuarrie; Edyta Stec-Uddin*
MillerCoors	*Greg Miller*
National Sports Center for the Disabled	*Nicole Robinson*
NEI Electric Power Engineering	*Clifton Oertli*
NTIA - Institute for Telecommunication Sciences	*Andrew Thiessen*
North LLC	*Jered Dean*
POWER Engineers	*James Trumble; Derek Sanders*

Segrity, LLC.	*Veronica Ferro; James Volk*
Shell	*Kyle Hilberg*
Southwestern Energy	*Rowlan Greaves*
StoneAge Tools	*Jerry Zink*
Traxion	*Chris Cone*
Trefny Innovative Instruction Center	*Timeri Tolnay*
University of San Francisco	*Seth Wachtel; Randolph Langenbach*
U.S. Ice Drilling Program	*Jay Johnson; Chris Gibson*
Woodward, Inc.	*Dr. Gregory Hampson*
Individual clients	*Amy Purdy*
	Shannon Lapham

Becoming a Client

The Capstone Design@Mines Program pushes students to go beyond their classroom training and solve real-world design problems. Every semester the college has over 50 student design teams who need great challenges to engage with. What opportunities does your organization have that could be addressed by a student team?

SPONSORSHIP FEE	Corporate project sponsors are asked to provide a sponsorship fee of $5,000, of which $2,500 is made available to the student team for purchasing materials. The additional amount is used to support program facilities, staff and overhead. Government agencies, NGOs and startups may request exemption from the suggested donation but are generally expected to pay for project materials.
TIME COMMITMENT	The involvement of the project sponsor is a key factor in the success of the project. Great project sponsors will commit one individual for approximately 1-hour per week to support the student team. In addition, any training or on-site resources that you can make available to the students are greatly appreciated.
OTHER	Student access to construction sites, manufacturing partners, or other company resources is always appreciated by the students.

GETTING STARTED
Check out our website at http://capstone.mines.edu/ for additional information on becoming a sponsor or send an email to design@mines.edu to start exploring opportunities with program staff.

General Information Regarding Trade Fair

JUDGE’S AGENDA

Time	Description	Location
7:30 – 9:00	Breakfast reception sponsored by the CSM Foundation	Student Center Ballrooms
8:30 – 9:00	Judge Registration/Check-in	Lockridge Arena
9:00 – 11:00	Trade Fair	Lockridge Arena

FINDING YOUR WAY AROUND

A floor plan of the Trade Fair is available on the back of this program for your convenience.

JUDGES LOUNGE

Snacks and beverages are available for judges in the Judges Lounge. Please feel free to take a break from talking with the teams and grab a beverage or snack in the lounge at any time.

GRADING

We seek to achieve consistency in grading between judges. With that in mind, the capstone design faculty have developed the Trade Fair Ballot to aid your judging. Each row includes prompting descriptions that are intended to guide the evaluation process. Each description has an associated point value with it.

To completely grade a team, please select a single number from each row of the grading matrix. Sum the numbers (one from each row) and enter the total team score at the bottom of the ballot. Please return the form to the registration table when it is complete.

Spring 2017 Design Projects

Each year senior students in the civil, electrical, environmental, and mechanical engineering programs in the College of Engineering and Computational Sciences take a two-semester course sequence in engineering design targeted at enhancing their problem-solving and communication skills. Corporations, government agencies, and other professional organizations, as well as individual clients, provide projects for the student teams to work on. Students spend the academic year developing solutions for the projects to which they have been assigned, using tools they have learned throughout their careers at Mines.

This semester, we are proud to present the work of 47 design teams. Their collaborative design work culminates in today's Capstone Design@Mines Trade Fair. A list of the teams is provided below. In addition, each team has provided a one-page synopsis of their design challenge which is included in the following pages.

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06	CH4 Engineering	Methane Plume Characterization
07	Catalyst Designs	Micro Portable Gas Generator
08	Team MINESat	MINESat Initiative
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10	The A/V Team	Mobile A/V Recording Booth
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12	Team S.B.M	Substation Model Challenge
13	Mad Hatter Mitigation Squad	Reducing Mercury Pollution in Small-Scale Gold Ore Processing in Suriname
14	Efficient Energetics	Retrofit Package for GRL Challenge
15	Get Rigged	Drill Rig Heave Simulator

Team Number	Team Name	Project
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17	Crash Engineering	Restraint System for EMTs
18	Team Pile Driver	Solar Load Testing Apparatus Challenge
19	PEZ Engineering	Sustainable Fish Feed Machine Challenge
20	Team Supa Suit	Wearable Technology: Smart Suit
21	Team Carbon Nation	Formula SAE Carbon Fiber Monocoque Challenge
22	Diggerloop	SpaceX Hyperloop Pod Competition II
23	Rooney Bin	Rooney Road Solar Challenge
24	Abominable Rowmen	ASCE Concrete Canoe
25	Licensed to Steel	ASCE/AISC Steel Bridge Competition
26	Overworked and Underpaid	ASCE/AISC Steel Bridge Competition
27	The Molebots	SPE Drillbotics Competition
28	Blasterbotica	NASA Robotic Mining Competition
29	CSM Baja Team	SAE Baja Competition
30	2 Efficient 2 Furious	Shell Eco-Marathon Competition
31	Team Yeti	Air Reverse Circulation Ice Drill Challenge
32	Team CNXS	Alternative Framing Connectors
33	GEOPamaka	Cedarville Rancheria Geothermal End Uses Challenge
34	Golden Connection	Community Connection Across I-70
35	The Notorious ENG Senior Design Team	Cuttings Volume Measurement Challenge
36	CSM EngiBEERing	DA Water Tower Challenge
37	BACOG	Digital Shower Valve Challenge
38	Get a Grip Engineering	Dynamic Automotive Wheel/Tire Test Machine
39	Team Goosenecks	Educational Model of the Goosenecks
40	anTEAMa	Embedded Antennas Challenge
41	Oxidizing Innovation	Evaluation and Pre-design of a Peracetic Acid Disinfection Challenge
42	Clairaudience	Hearing Aid Eye Glasses Challenge
43	Team GreenWorks	Food Computer Challenge

Team Number	Team Name	Project
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45	Banding Together	Gabion Band Ring Beam Challenge
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46d	Human Centered Design Studio	Adaptive Saddle
46e	Human Centered Design Studio	Snowboarding Prosthetic Foot/Ankle
46f	Human Centered Design Studio	Bi-Ski Impact Outrigger
46g	Human Centered Design Studio	Smart Pill Box
46h	Human Centered Design Studio	Transfemoral Prosthesis Joint
47	Team Hydro	Hydro Turbine Governor Test Stand Challenge

2016-2017 AIAA Design Build Fly

01

Client(s): Angel Abbud-Madrid
Faculty Advisor: Robert Huehmer
Technical/Social Context Consultants: N/A
Team Name: *BurroWorks*
Team Members: Nicholas Bean, Sam Drescher, Ben Holland, Ian Kramer, Marie Pisciotta, Josh Schechter

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The American Institute of Aeronautics and Astronautics (AIAA) Design Build Fly (DBF) competition is an international competition in which university teams from around the world design Unmanned Aerial Vehicles (UAV) to meet a set of goals. After a half a year of testing and submitting design reports, teams meet in Tucson, Arizona on April 20-23 to fly off against 80 other teams. This is team *BurroWorks*' second year attending the competition.

The goal this year was to design a "tube-launched" UAV. The aircraft was required to fit inside a compatible storage tube and be portable. To simulate a utilitarian payload UAV, the aircraft was required to carry a payload of at least three regulation hockey pucks and fly laps around a designated course.

Team *BurroWorks* designed, built, and tested a lightweight aircraft designed to maximize the score. Based on lessons learned from the previous year, the team constructed the aircraft primarily out of balsa. The aircraft features sufficient power and aerodynamics to reach a blistering speed of 100 MPH. The aircraft is capable of carrying up to five hockey pucks at full throttle with an endurance of over five minutes. Utilizing folding mechanisms that minimize the packed volume of the aircraft means it can be stowed in a tube measuring only 7" x 37".

Low-Cost Power Wheelchair

02

Client: North LLC
Faculty Advisor: Dr. Jeffrey Schowalter
Technical/Social Context Consultants: Dr. Joel Bach
Team Name: Mobility Simplified
Team Members: Cody Clayton, Colby Towle, Evan Powell, Joshua Cunningham, Justin Ray, and Nicholas Martinez

The objective of the Low-Cost Power Wheelchair Challenge was to design and prototype an affordable secondary power wheelchair, particularly for travel purposes. Through research and interviews with families of wheelchair users and chair resellers, the team found that cost savings in the commercial production of daily-use chairs are often not passed on to the consumer. Also, these chairs are often very difficult to travel with, making portable and affordable secondary chairs a necessity for many users. Some of the required parameters laid out by the client, North LLC, include tilt and recline abilities, meeting and exceeding most general wheelchair regulations, creating a back door system in which an autonomous control system can be incorporated, a tip-angle warning system, and 8-degree slope capabilities in all directions.

The team opted for a foldable design to make storing and transporting the chair as easy as possible. The seat for the prototype is a repurposed automotive seat, which comes with a manual recline mechanism up to 135 degrees. This is attached to the base of the chair through two mounted ball bearings on a steel tube near the back of the seat, and two linear actuators supporting the front of the seat. The actuators provide the mechanism which allows the seat to tilt and hold the chair at any angle between 0 and 45 degrees from the horizontal. The base structure consists primarily of steel rectangular tubing, which offers numerous advantages in cost, weight, and manufacturability.


Figure 1: Conceptual design of wheelchair

As for the electronics and control systems, the wheelchair has two brushless DC (BLDC) motors for maneuvering. These motors have a convenient form factor, and are more efficient than traditional DC motors. A TI-F28069M microcontroller is used to control the motors and gather input from the user. The control panel consists of a joystick, a mode selection switch, a battery level indicator and a tilt warning light. The controls are all conveniently mounted on the armrest for easy access.

Low Cost Solar Cooker with Energy Storage

03

Client(s):	Dr. Gregory Jackson
Faculty Advisor:	Donna Bodeau
Technical/Social Context Consultants:	Dr. Paulo Tabares-Velasco
Team Name:	It's Always Sunny in Golden
Team Members:	Skyler Morris, Ben Marum, Ali Alsudari, Thomas McWhirter, Xuan Tran, Jacob McClean

The solar cooker is designed to have three different units: Collection, charging, and cooking. Each unit is incorporated into a two-loop system. The working fluid, a mineral oil, flows through the loop from one unit to another. The fluid's path initially starts at the collection unit, located in the first loop of the system, where it collects the solar energy. It then moves to the charging unit, where the energy collected prior is used to charge a phase changing material (PCM), a eutectic mixture of 60% sodium nitrate and 40% potassium nitrate. The fluid then flows back to the collection unit, where it either continues collecting and charging the PCM, or enters the second loop, where it is used to heat up a cooking surface. In addition to the three units, the system contains three subunits: a gear pump, oil tank storage, and valves. The gear pump drives the flow of the working fluid through the loops. The gear pump is also responsible for adjusting grill surface temperatures. The working fluid is expected to expand as it flows through the loops. To alleviate pressure build up, an expansion oil tank is provided.

Lower North Empire Creek Restoration

04

Client(s): Dave Holm, Clear Creek Watershed Foundation
Faculty Advisor: Branden Gonzales
Technical/Social Context Consultants: Robin Bullock
Team Name: The Mudsliders
Team Members: Kaitlynn Bullock, Emma Elefante, Kohl Knutson, Kianna Lee, Mary Weiss

Empire, Colorado is located forty-two miles west of Denver, Colorado. North Empire Creek Basin, located north of Empire, once held one of the most affluent gold mining sites within Clear Creek County. As a result of the mining extraction and treatment processes, the land, surface waters, and plant life of the North Empire Creek Basin were contaminated. Evidence of this contamination has been determined by multiple entities, including Colorado School of Mines students in both Environmental Field Session and Senior Design, and private companies such as JW Associates.

The previous engineering efforts conducted by students and companies, described above, involved characterization of the site and identified regions in dire need of reclamation and further design efforts. Based on these assessments, the Executive Director of the Clear Creek Watershed Foundation, Dave Holm, had reason to suggest that the removal of mine waste piles and contaminated sediment would significantly reduce water contamination downstream. This theory is supported by water quality test results gathered by Colorado School of Mines students during Environmental Field Session. The basin region that contains these piles and contaminated sediment is depicted in Figure 1. The *Mudsliders* were tasked with addressing the contamination taking place in the region by compiling a process and design for the removal of the tailings piles and contaminated sediment in the basin. The plan the Mudsliders compiled proposes to excavate the waste piles and contaminated sediment, place the contaminated material from the piles into a prepared storage area, top the relocated contaminated material and reshape the channel using clean soil and topsoil. All proposed remediation efforts are conducted in hope to improve and prevent further potential contamination of Clear Creek and thus additional surrounding bodies of water.

Figure 1: Project Site

Medium Voltage Switchgear Transfer Scheme and Structural Engineering

05

Client(s):	NEI Electric Power Engineering
Faculty Advisor:	David Young
Technical/Social Context Consultants:	Dr. Sen and Dr. Crocker
Team Name:	Team Ramrod
Team Members:	James Neal, Amy Jensen, Nick Withers, Joe Rushin, and Nic Van Kooten

NEI Electric Power Engineering requested consultation to build an electrical system upgrade to their existing industrial plant. This required that Team Ramrod determine the power distribution needs of the overall system and outfit the necessary switchgear for the system. Along with this, Team Ramrod sized all other electrical equipment including surge protection, and circuit breakers. Team Ramrod also performed the design for the structural layout and grading plan of the electrical equipment and its housing. In addition, the client requested that Team Ramrod perform a transfer scheme for the electrical distribution system. This transfer scheme ensures that the industrial loads will still be supplied in the event that there is a power outage from the utility power. When a utility system outage is detected, the industrial loads will then transition and be fed by a 1.5 MW generator, which will happen automatically. This will all be controlled by a GE-850 protection relay. Team Ramrod programmed the GE-850 relay to ensure that everything transitions smoothly.

Figure 1-Wiring of Panelboard

Figure 2-Structural Design for Electrical Building

Figure 3-Panelboard to Represent Electrical System

Since Team Ramrod's project is design only, and there is no actual physical deliverable, Team Ramrod decided to create several physical models of the design to show at Trade Fair. One will be a panel board which will represent the electrical switchgear, buses, circuit breakers, and switches of the overall system. This will all be controlled by the GE-850 relay which will demonstrate the transfer scheme that Team Ramrod has programmed. Second, there will be a physical cross section of a duct bank to showcase the structural calculations the civil engineers performed.

Methane Plume Characterization

06

Client(s): Ball Aerospace
Faculty Advisor: Donna Bodeau
Technical/Social Context Consultants: Neal Sullivan
Team Name: CH4 Engineering
Team Members: Rachel Bruce, Dakota Burgerhoff, Charles Henry, Daniil Tashlykov

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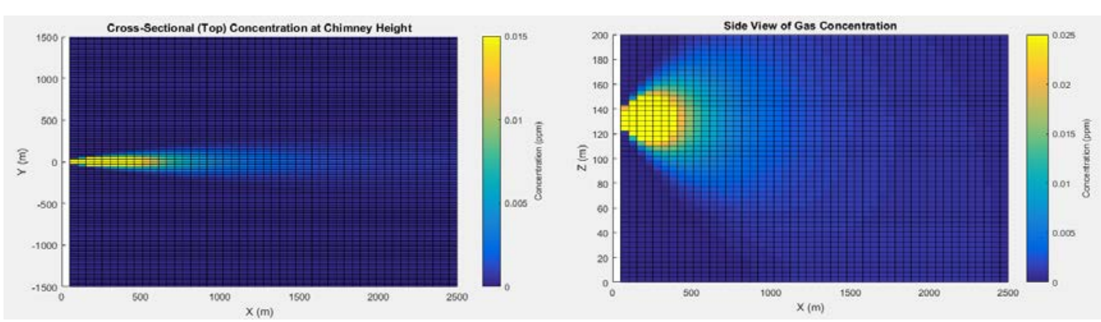
Gas pipelines are used every day to fuel communities with energy. These lines typically run underground for extremely long distances. In some cases, lines may leak and cause harmful gases (such as methane) to seep out of the ground and into the atmosphere. Having a solution to characterize these plumes in 3D would help companies to better solve leaks in the supply & return lines. Ball Aerospace has called on the CH4 Engineering Senior Design Team to engineer a software/apparatus combination to solve this prominent gas line problem.

We created an apparatus from 80-20 extrusions and an aluminum base plate that is radially machined to allow for 16 directions of measurement in 22.5 degree increments. The basic design is comprised of two extension arms, though up to sixteen can be attached, that will allow us to measure methane concentrations up to fifteen feet away from the central release point and as high as ten feet in the air.

The number of data points collected is highly customizable and can be decided by the user. For testing purposes, these methane concentration data points will be collected using calibrated MQ-4 adafruit sensors. However, the user can apply any sensor they desire. Using these methane concentration points, as well as current weather information gathered by auxiliary sensors, we will simulate a plume model showing both plume shape and density on site via a central module controlled by a Raspberry Pi 3 board.

The Raspberry Pi receives information from the MQ-4 methane sensors in voltages, which are converted to Methane PPM (parts per million) values through a calibration curve developed in the preliminary stages of apparatus testing. Using the PPM values and XYZ coordinates for each sensor in relation to the main hub, a Gaussian Plume model is developed using a least-squares regression method. This methane plume can be modeled over time and is affected by weather conditions recorded by the auxiliary sensors (wind speed/direction, temperature, pressure) in the central hub. An example Methane Plume Model generated by MATLAB is shown below.



Micro Portable Gas Generator

07

Client(s): Dr. Gregory Hampson of Woodward, Inc.
Faculty Advisor: Dave Young
Technical/Social Context Consultants: Dr. Gregory Bogin
Team Name: Catalyst Designs
Team Members: Ryan Blarr, Austin Ellis, Keegan Favill, William Garland, Kougar Lott, Colin Peter

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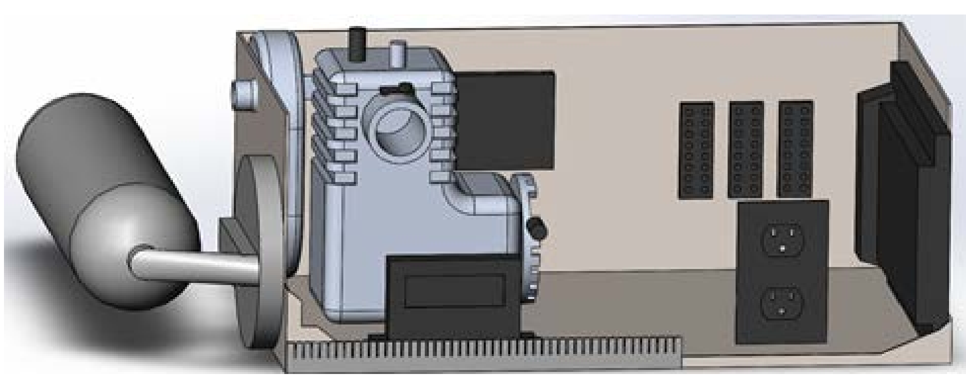
Engines that have the ability to run on various fuels are an important component to the future of power generation. To this end, Woodward Inc. approached the team with the task of designing a portable generator system that would run on a wide range of continuously varying, gaseous fuels.

The product of this effort was designed to be used as an analytical tool for the company. The capabilities of this generator are provided by the engine control unit (ECU), which utilizes the Woodward softwares: Motohawk and Mototune. Code within these programs controls combustion characteristics through spark timing, speed, and air-fuel ratio while providing real time feedback via PID control. This provided feedback, which includes fuel flow rate, location and magnitude of peak pressure, power output, and burn duration, is used to test and diagnose larger commercial engines in the field. These engines are typically larger units utilizing the same ECU included in this generator and may also run on any type of gaseous fuel: methane, propane, or natural gas, to name a few. It is for this reason that the generator must be capable of accepting any liquid or gaseous fuels.

The product can also be used purely as a generator for people without access to electricity through other means, via connection to sources such as a natural gas line or tank of propane. Both AC and DC power supplies are provided by the unit with output values capable of charging portable electronic devices such as laptops or cellular phones. Honda components included with the stock generator unit at the core of this design reliably provide this electric capability.



MINESat Initiative

08

Client: Dr. Atef Elsherbeni
Faculty Advisor: Dr. Randy Haupt
Technical Consultants: Dr. Payam Nayeri, Dr. Angel Abbud-Madrid
Shawn Kobylinski, Darren McSweeney
Team Name: Team MINESat
Team Members: Mark Anderson, Vu Dang, Sam Friedman, RJ Gibson,
Duc Nguyen, Nick Smith, Luke Waguespack

The goal of the MINESat Initiative is design, develop, and launch a 3U CubeSat (30×10×10 cm3 nanosatellite weighing less than 4 kg) into low earth orbit. The CubeSat's mission has not been determined yet, but it is anticipated to carry a geophysical sensor. The project is reaching the end of its third year, with each year's team continuing the prior team's work. The first year's team developed basic designs on the communications and power systems, and performed initial testing. The next year's team advanced the design to include space-rated components, a communications system conforming to CubeSat protocols, and initially developed attitude determination and control systems. This year's goal was to further develop all the subsystems for the satellite, integrate them into a working prototype, and test the system as a whole.

The satellite prototype includes a magnetic de-tumble system for stabilization once ejected from the launch vehicle, a reaction momentum wheel assembly for orientation control, and a VHF/UHF antenna communications system.

The team developed a frictionless platform to test the satellite's attitude control systems (Figure 1). The bed uses a spherical air-bearing to allow rotation about three axes. The communications system will be tested by taking a photo and transmitting it to the ground station on top of Brown Building, which was implemented by last year's team.

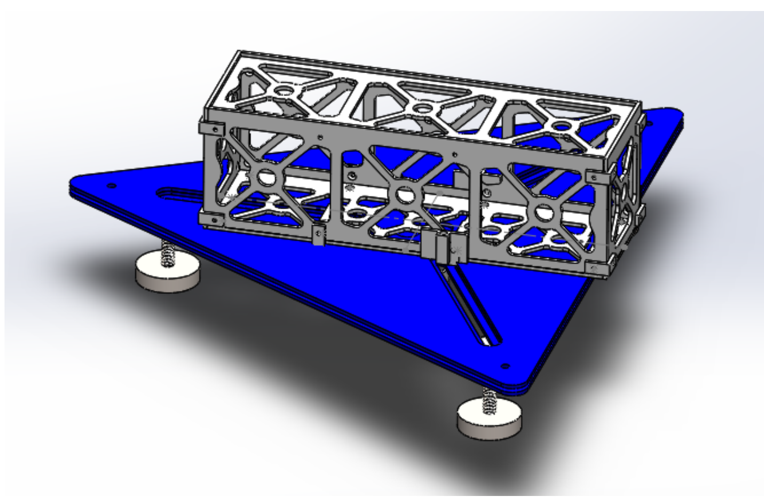


Figure 1: Prototype chassis on frictionless test bed platform.

Mobile Internet of Things Testbed

09

Client(s): Andrew Thiessen
NTIA - Institute for Telecommunication Sciences
Faculty Advisor: Adam Duran
Team Name: Apple of my IoT
Team Members: Caleb Waitsman, Jaydee Griffith, Chris Willecke, Matt Wilson, Xiaoyang Liu, Pranav Sharma

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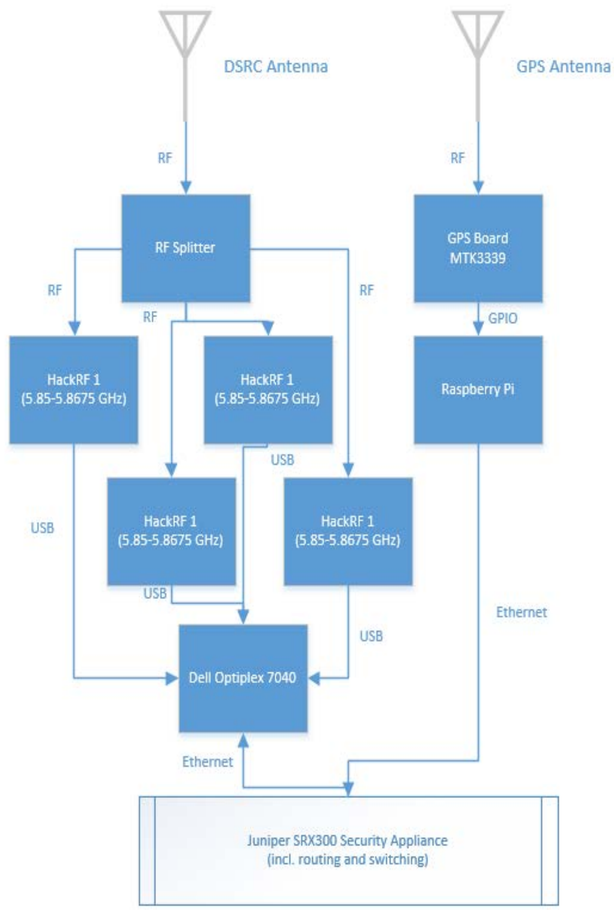

The Internet of Things (IoT) has become popular as a technological concept to integrate user devices and infrastructure with broader network architectures. Connecting devices on the road to a network of information can simplify multi-tasking and minimize distracted driving incidents. Despite the rise in popularity of IoT technologies, very little has been done to test the feasibility of integrating infrastructure, specifically within the automotive industry. The goal of this project is to provide a mobile test-bed for IoT technologies focusing on DSRC (Dedicated Short Range Communications) signal. Specifically, we are going to display in real time and store IoT data in a vehicle on the go. This test-bed has the capability to measure, process, and store DSRC signal strength and GPS information. Through a process of cross-referencing to align data based on a time stamp, our team has been able to compare IoT traffic across different locations. The figure shown on the right demonstrates the overall system for the mobile test-bed and the data flow of how DSRC signals being processed. Our team has optimized the design by building a four-HackRF spectrum analyzer system to reduce cost and increase power efficiency. Our team will be presenting a prototype signal acquisition and data storage system. We are also displaying experimental test results based on information gained from GPS and the DSRC signal.

Mobile A/V Recording Booth

10

Client(s): Trefny Innovative Instruction Center
Faculty Advisor: Eric Bonnema
Team Name: The A/V Team
Team Members: Wassam Alqahtani, Evan Boynton, Roy Brown, Curt Dennis, Ruben Jackson, Connery Reid

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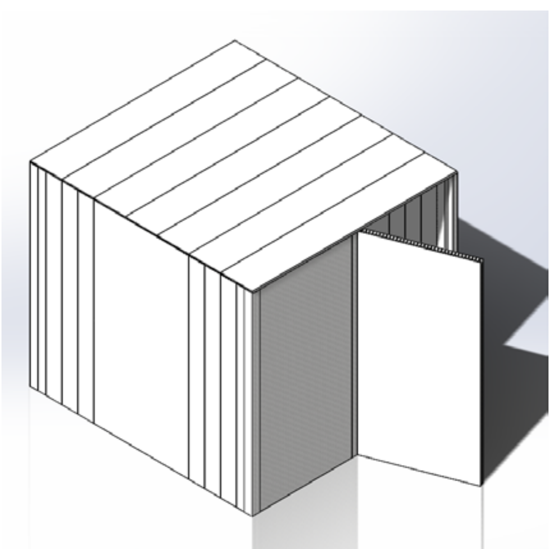
The Trefny Innovative Instruction Center has tasked the A/V Team with designing and constructing a portable, lightweight, and soundproof audio/video recording studio to be set up and utilized during campus events. The primary use of the studio is to allow alumni to inform current students of their experiences (before and after graduation) through short video interviews. In order to produce high quality content, the studio will utilize a green screen and professional lighting in conjunction with a high-definition webcam. These devices must be integrated seamlessly into the design. Furthermore, setup is to take around 30 minutes and be conceivable in any building on campus.

Extrutech® clean room panels make up the structure due to their lightweight and modular design. The PVC material is able to create a tight seal, which aids in soundproofing. A 7’ long, 6’ wide, and 6’ tall configuration has been chosen, leaving space for a media wall at the front and enough width for green screening and seating. Though a height of 6 feet does not enable all individuals to stand upright in the room, this will not be an issue since users will be recorded in a seated position. The height reduction greatly increases portability.



All electronics run off of 120VAC power (through an extension cord or batteries) in order to maximize viable setup locations. The dedicated media wall contains a touch-screen computer making use of a shotgun microphone and webcam. Lights attach at the edges of the media wall to illuminate the interviewee, and around the green screen to facilitate post-production masking.

To make the studio welcoming and aesthetically pleasing, the A/V Team is considering exterior vinyl decals.

Office Power Meter Challenge

11

Client(s): Burns & McDonnell
Faculty Advisor: Dave Young
Technical/Social Context Consultants: Salamon Mohagheghi
Team Name: PowerWatch Solutions
Team Members: Aaron Bonenberger, Kenneth Kooy, James Kor, Tailor Noehring, Jacob Shonka, John Skeath

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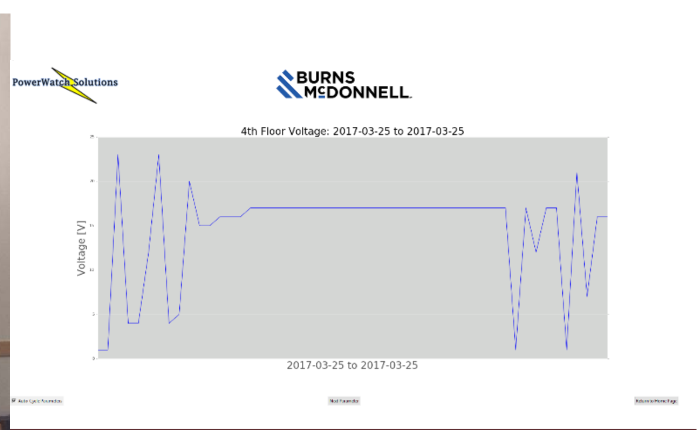
The PowerWatch team has created a project which measures power consumption of the client's building so they can identify potential energy savings and measure the effectiveness of energy savings initiatives. The team came up with a design that incorporated feedback from the team’s consultant, Faculty Advisor, and client. From the captured signals, the team produced software to analyze the multiple electrical parameters of the signals to quantify and store electrical data such as power factor, overvoltage, and undervoltage. The data can be displayed numerically or graphically on a User Interface (UI) found on the client’s site. Machined enclosures house all electrical equipment on the client’s office building.

The team’s exhibit will showcase major subsystems of the project. A physical copy of the circuit used to measure the electric signals for the fourth floor will be actively recording data for a simulated load. There will also be a copy of the enclosure used at the site to house the RaspberryPi 3B and custom circuit. The team will also have a mock-up of the data collected from the site displayed on the custom UI displayed on a laptop.

PowerWatch Solutions used many engineering techniques and coding libraries to meet the client’s needs. The UI was coded in Python 3.5 using the Tkinter library and it communicates with the PostgreSQL database wirelessly on a Local Area Network. The custom circuit utilizes a DC biasing, capacitive filtering, and A/D conversion to capture the current and voltage signals from Current Transformers (CT) and Voltage Transformers (VT), respectively. The circuit is housed in an altered enclosure in addition to a RaspberryPi 3B acting as the processor for the sensor. The sensor Python code collects, computes, and wirelessly transmits to the database.



Substation Model Challenge

12

Client(s): POWER Engineers
Faculty Advisor: Dave Young
Technical/Social Context Consultants: Pankaj Sen
Team Name: Team S.B.M
Team Members: Matt McFadden, Curt Feinberg, Brad Bond, Tanner Howard and Jessica Hernandez

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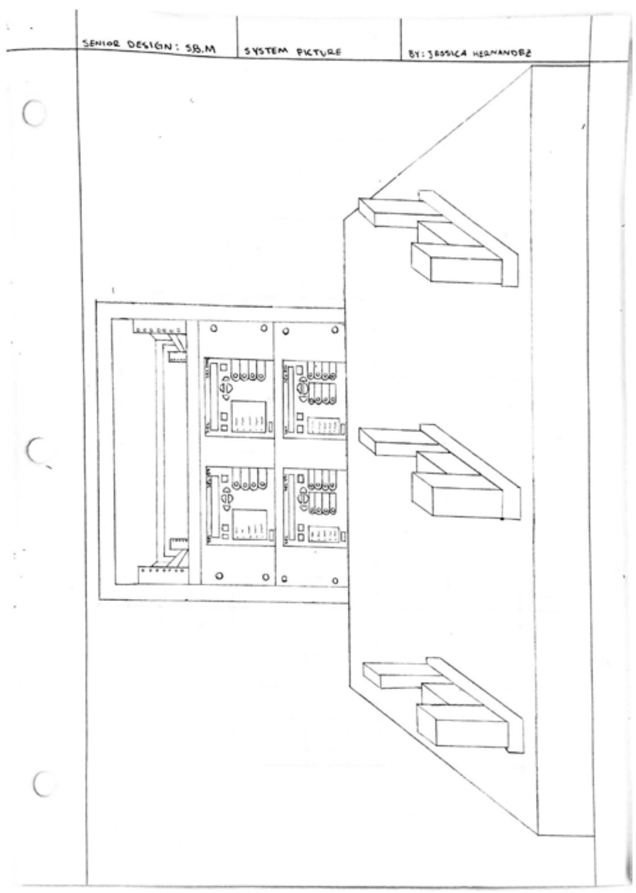
The purpose of the Substation Model Challenge was to create a working substation model that integrated with relaying protection and SCADA communications. The team developed a system that integrates the existing SCADA communications and relay devices that were created by last year's design team. The system has circuit breakers on both sides of the transformer connected to relays. The relays measure the current that goes in and out of the system and determines if it is within the appropriate current range. If the current exceeds the range, then the circuit breakers will trip to de-energize the system and protect the components. If the current gets too high in the system, it could overheat and damage many of the components. Replacing the damaged components in the real world would be expensive and time consuming.



The model will be connected to three single phase loads. The team decided to model the loads as a city, using light bulbs to light up the buildings. Light bulbs were selected to simplify the calculations and to create an interesting and fun display for trade-fair. When one or two of the loads are turned on, the lights in the buildings will stay on. As soon as the third load is powered on, all the loads turn off, simulating a blackout. The picture to the right shows the three separate loads on the table along with the relays in the back.

Reducing Mercury Pollution in Small-Scale Gold Ore Processing in Suriname

13

Client(s): Nicole Smith
Faculty Advisor: Benjamin Teschner
Technical/Social Context Consultants: Hugh Miller, Josh Sharp, Erik Spiller
Team Name: Mad Hatter Mitigation Squad
Team Members: Thomas Carter, Emily Davis, Emiley Lopez, Erika Nieczkoski, Laszlo Panyi, Carl Scheevel

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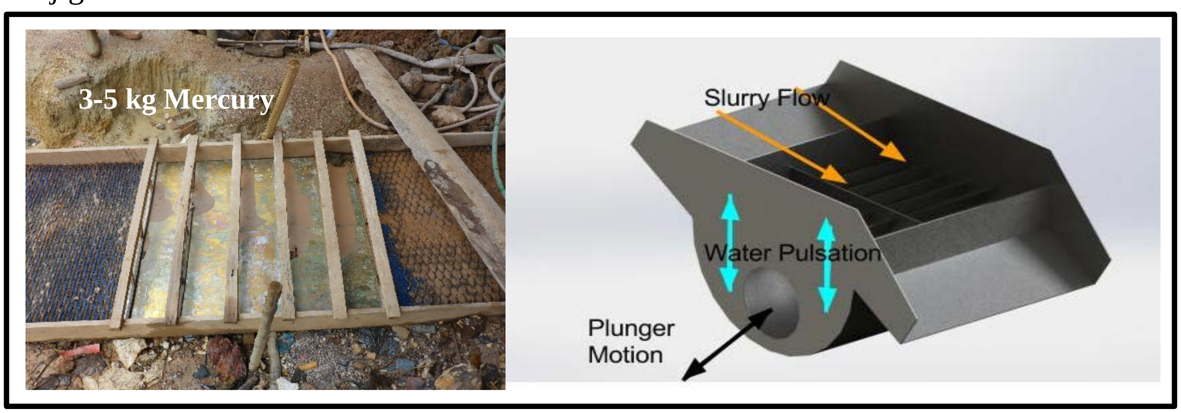
The primary goal of this project is to create a method for refining gold at alluvial artisanal and small-scale mines in developing countries that will reduce the amount of mercury that is being used and subsequently released into the air and water resources. Mercury is both environmentally damaging and hazardous to human health. The current system for gold ore processing at pit mine sites in some areas of Suriname involves the usage of 3-5 kilograms per month of liquid mercury in each of the "brandkas" (pictured below) that follow the mine's crushing circuit. We designed a method of gravity separation to replace the "brandkas", therefore eliminating the largest single point source of mercury in the current mining practice.

The gold ore jig (below right) has an input of ore slurry and clean hutch water. A rubber diaphragm pulsates the water and fluidizes the mineral bed. The ore components will then separate out according to specific gravity, and gold, the densest mineral in the ore, will precipitate to the bottom of the jig.



The "brandkas" (left) uses 3-5 kilograms of merucury per month and will be replaced with the gold ore jig (right).

The gold ore jig uses materials that are easy to source in rural areas of Suriname, and it is simple to construct. The upfront cost to design the full-scale jig is roughly $1,100. Artisanal and small-scale miners who do not have to pay for mercury would be able to invest these funds in the gold ore jig. Our team hopes that miners will use our design to construct gold ore jigs at their sites.

This is an EPA P3 funded project and our team will be traveling to Washington D.C. in May to present at the TechConnect World Innovation Conference and Expo. We would like to thank Dr. Marieke Heemskerk and Jurgen Plein from Suriname for visiting and helping our team with this project.

Retrofit Package for GRL Challenge

14

Client(s): Paulo Cesar Tabares-Velasco
Faculty Advisor: Eric Bonnema
Team Name: Efficient Energetics
Team Members: Samuel Bismuth, Patrick Council, Casey French, Yuliang Jin

The objective of the General Research Laboratory (GRL) challenge was to reduce the 2015-16 electric peak demand level by 20%. Peak demand is a term used in energy demand management to describe a period of time in which the electrical power required is above the average supply value. Power generation plants must keep large generation units on reserve, which is cost prohibitive and inefficient, in order to meet the short-lived peak demand period. By meeting the goals of the GRL challenge, stakeholders including: students, parents, faculty, maintenance staff, and the City of Golden, benefit from the resulting lower electricity cost and cleaner environment.

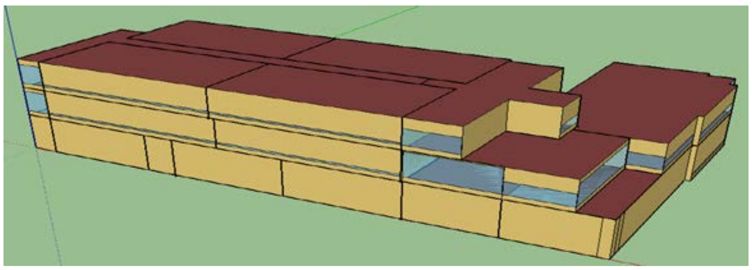


Figure 1. SketchUp and OpenStudio Building Model of GRL

The challenge required the implementation of several peak shaving concepts, all of which must have a return on investment no greater than 10 years. The team used SketchUp software to build a 3D model of the GRL (Fig. 1) based on the architectural drawings. The team then used OpenStudio to simulate the GRL power demand with the implementation of three peak shaving concepts.

Efficient Energetics used three methods to lower the peak demand: simulated a thermal ice storage system for heating and cooling, implemented a solar array plan coupled with battery storage to reduce the power draw during peak daytime hours, and planned to retrofit an LED package to lower the overall power demand. Thermal ice storage freezes a large block of ice during the off-peak hours, air is then passed over the block to cool the building. Due to the high portion of the GRL energy demand dedicated to HVAC, ice storage reduces a considerable amount of energy. Solar power generation coupled with battery storage has a potential of reducing peak demand by 10%, while still meeting the challenge goals.Moreover, lighting load is another large part of the peak demand. Most of the lights in GRL are fluorescent. Switching the lights to LEDs reduces the lightning load by 50% and peak demand by 16%. The solar panel saves about 10% of the electricity bill. Energy savings of at least 20% has been achieved by planning implementation of those three concepts.

Drill Rig Heave Simulator

15

Client(s): John MacPherson & Hans Uwe Brackel, Baker Hughes
Faculty Advisor: William Yitz Finch
Technical/Social Context Consultants: Buddy Haun, John Steele, Jorge Sampaio
Team Name: Get Rigged
Team Members: Taishiro Okazaki, Joseph Symmach, Ryan Unruh, Dylan Wollett

Our team is developing a machine that will accurately simulate the motion of an offshore drill rig subject to wave motion. Our client, Baker Hughes, plans to use the machine as a piece of lab equipment to research new measurement systems to be implemented on offshore drill rigs in the future. The simulator must be able to handle 360 degrees of directionality; this means that the wave can impact the platform at any point and angle direction not just perpendicular to the sides. The simulator also features a moving block at the center of the table that will remain in the same vertical position regardless of table position. This is to simulate the drill bit at the bottom of the ocean; it cannot move during operation or it risks damaging itself or the well.

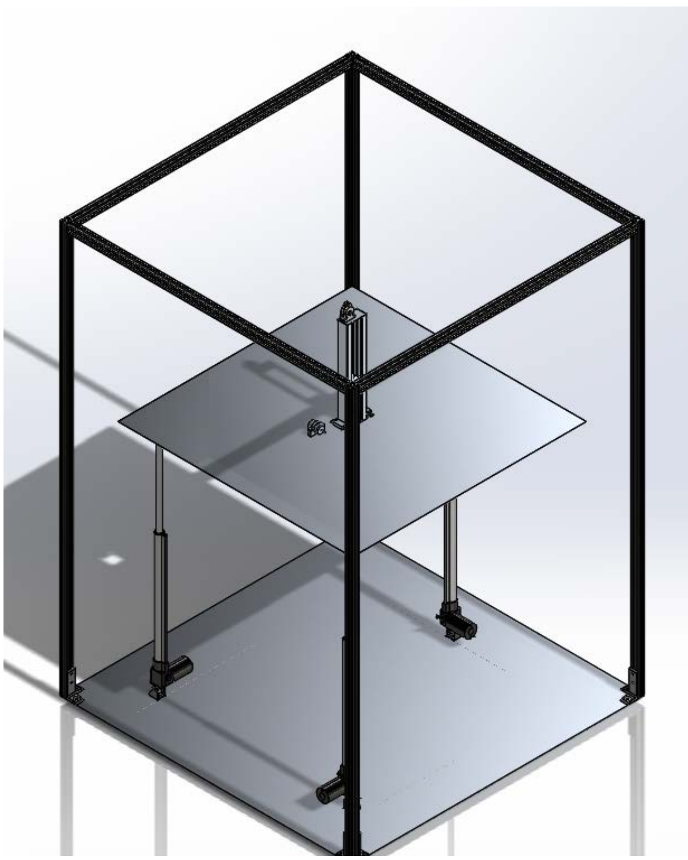


Figure 1: Isometric Representation of the Full Simulator

To accomplish this task, the team is developing a unique solution to use three linear actuators. Measurement will be accomplished using three inertial measurement units (IMU) and three ultrasonic sensors. The IMU's will track the vertical movement of the table as well as the pitch and roll. The ultrasonic sensors will measure tabletop displacements and feed that data back to the actuator controller to ensure they are outputting the correct waveform.

Robot-Assisted Comfort Sensing Device

16

Client(s): Dr. Paulo Tabares
Faculty Advisor: Eric Bonnema
Technical/Social Context Dr. Hao Zhang
Team Name: Team Tranquility
Team Members: Junquan Lin, Joaquin Ortega, Megan Richards, Patrick Sobolewski, Graham Weeks, Reno Wood

Figure 1: The overall system (Turtlebot and sensor enclosure).

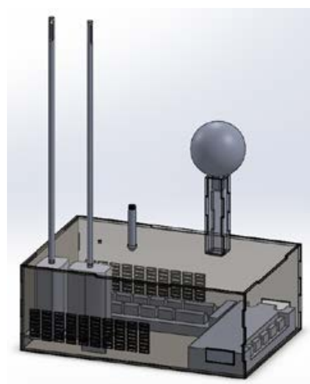


Figure 2: The sensor enclosure with all of the sensors and DAQ inside.

The objective of Team Tranquility's project is to create a device that can determine indoor comfort conditions by collecting data from around a room using various sensors attached to a mobile robot called a Turtlebot. By measuring air temperature, radiant temperature, humidity, and air velocity, we can compute and map comfort data by using written programs to move the Turtlebot and take data at various positions.

The data is stored in a database where it can be analyzed and visualized, then used to determine if actions should be taken to make a room more comfortable, such as installing a fan or changing the thermostat.

Our design uses five sensors that we decided are most effective in establishing comfort level. These include an ambient temperature sensor to measure the immediate air temperature, a radiant temperature sensor to determine the infrared radiation of the room, a humidity sensor to evaluate the relative humidity, and lastly, two anemometers to assess the lateral air velocities. By using these values and a program designed from ANSI/ASHRAE Standard 55-2013: Thermal Environmental Condition for human Occupancy, we can calculate the comfort level. This comfort level is calculated by determining what the standard effective temperature an individual would feel while wearing typical work clothing in a room with 50% relative humidity, average room temperature of 25℃, and less than 0.1 m/s air velocity. The data is stored in a database using MongoDB and saved to a server. In the future, this system may be implemented for direct building communication and environmental control.

Restraint System for EMTs

17

Client(s): Brandon Daruna, Gilpin Emergency Medical Services
Faculty Advisor: Eric Bonnema
Team Name: Crash Engineering
Team Members: Patrick Boyker, Evan Campbell, Mitchell Moore, Jeffrey Shapiro, Gouthami Sunku

Each year, there is an average of 4,500 traffic related crashes involving ambulances resulting in 2,600 injuries and 33 deaths. In these crashes, Emergency Medical Technicians (EMTs) are five times more likely to be killed than the driver. EMTs face these odds because the type of restraint system currently used impedes their ability to care for patients and therefore is often disregarded. Most of the injuries experienced by EMTs consist of head, neck, and spinal injuries. For the EMTs, most fatal injuries occur during emergency situations.

Figure 1: Reverse side of deflated vest

Gilpin County Emergency Medical Services has provided Crash Engineering with the opportunity to develop a proof-of-concept for a product that can both protect an EMT during an ambulance crash and maintain their mobility to provide patient care. Crash Engineering developed a modified airbag vest to protect the neck, back, and spine of the EMTs in the cabin of the ambulance. The vest utilizes accelerometers, a solenoid, and an electronic prototyping platform to detect crash situations and properly inflate. The vest requires only that it is worn and turned on. Since this design does not include any tethering to the ambulance itself, the EMT will have unrestricted movement throughout the cabin.

Figure 2: Vest worn in front of donated Gilpin Ambulance

This system meets the needs of Gilpin County Emergency Medical Services and other EMTs. Because EMTs are already required to wear a reflective vest on call, their existing vest can be replaced by the airbag system, which makes medical service providers more likely to adapt this technology. With Crash Engineering's airbag vest system, EMTs can operate within the cabin of the ambulance and save lives while decreasing the risk of their own.

Solar Load Testing Apparatus Challenge

18a

Client(s): Kleinfelder
Faculty Advisor: Robert Reeves
Technical/Social Context Consultants: N/A
Team Name: Team Pile Driver
Team Members: Caleb Chee, Chris Bishara, Cohen Turner, Nick Daskalakis, Patrick Hritz, Peter Contreras

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The Solar Load Testing Apparatus Challenge requested a design to safely and accurately test the soil strength at solar array development sites to optimize pile design. The current methods are unstandardized with many sources of error in the data collection process. The use of chains makes the deflection data inaccurate, and the current use of dial gauges requires a technician to be in close proximity to large forces being applied, creating an energy release hazard. Not only are current practices inaccurate and unsafe, the setup requires large equipment to be present on site and significant set up time for each loading condition. In order to gather all the necessary data for efficient pile design, the apparatus must be able to apply loads used to generate lateral and vertical deflection of wide flange piles, which will be measured in a safe and reliable manner. Team Pile Driver created a Modular Trailer Design that uses hydraulic jacks and digital gauges to collect pile data as shown in Figure 1.

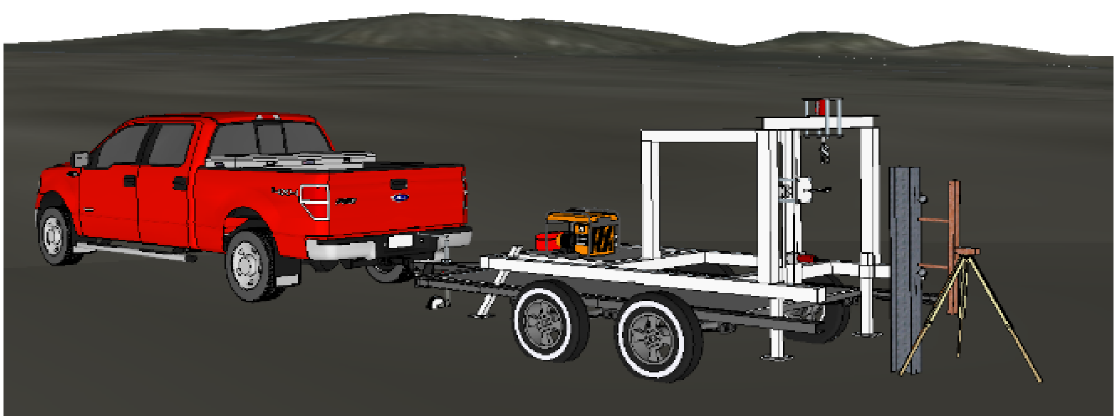

Figure 1: Modular Trailer Design

The trailer itself is mobile, allowing for easy transportation across large distances between sites. The trailer design allows for quick and easy setup and reliable automated data collection. The reduction of set up time and physical labor enables a crew to test more piles in a work day, increasing the efficiency of the testing and reliability of data through automation. The Modular Trailer Design can be applied to any trailer with minor modifications, and is capable of applying a moment couple to more directly test the soil properties for pile design, which is currently not an option with present testing methods. These improvements of the testing process will enable more efficient and reliable pile design for solar arrays, with increased safety and usability.

Repurposing Scrapped Electric Vehicle Battery Challenge

18b

Client(s): Hazen
Faculty Advisor: Robert Reeves
Technical/Social Context Consultants: N/A
Team Name: Team Pile Driver
Team Members: Caleb Chee, Chris Bishara, Cohen Turner, Nick Daskalakis, Patrick Hritz, Peter Contreras

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The Repurposing Scrapped Electric Vehicle (EV) Battery Challenge purpose is to develop a faster charge than current methods for electric vehicle through usage of recyclable batteries. Current means for charging are deemed either Level 1 or 2. For a Level 1 charge, the vehicle would need to charge for almost the entire day when connected to a 120V wall outlet, while the Level 2 charger, requiring a 240V wall outlet, could require up to eight hours for a full charge depending on the individual vehicle's battery capacity. The goal of the wall charger is to allow for a quick charge of an EV inside the homeowner's garage. By incorporating recycled batteries into a Level 1 or 2 charger, energy can be stored while the car is away and then used to quickly recharge the battery. This type of charging is sometimes referred to as Level 3. The team researched the feasibility of recycling EV batteries but found that the current demand is too high, and the supply is too scarce to economically repurpose them for consumers. In the future, these batteries may become more accessible, but for the time being the team turned to more economically practicable options. Due to market research and a lack of feasibility in current markets for used electric vehicle batteries, the team pursued other types of used batteries, such as cell phones. The final design can conceptually be applied to any used battery types, requiring only physical design changes.

For owners with longer commutes, road trips, or simply days with many errands to run, the designed QUEStCharger allows an electric vehicle owner to trickle charge the battery blocks using a standard 120V outlet while the car is away. The EV can then use this stored energy to quickly charge its battery at a fraction of the time required for a standard Level 1 or 2 charging. As electric vehicle battery capacities and ranges increase, cars will require more power but charging from a 120V outlet will remain the same. The modular design gives electric vehicle owners the ability to personalize charging station capacity without rewiring their home. The QUEStCharger enables more of a charge to be delivered to the car battery in a shorter time span, allowing the owner to use nearly the entire range of the car in a day and still receive a full charge by the next morning.

Sustainable Fish Feed Machine

19

Client(s): The Invictus Initiative
Faculty Advisor: Robert Reeves
Team Name: PEZ Engineering
Team Members: Gavin Meyer, Mat Drotar, Albert Lima, Gary Powers, and Jesaja Lemke

The Sustainable Fish Feed Machine Challenge was created by The Invictus Initiative in order to further achieve their goal of bringing a village school in Kenya to a point of prosperity and self-sustainability. The Invictus Initiative implemented an aquaponics system at the school, and identified purchasing fish food as the largest ongoing cost. As a result, The Invictus Initiative tasked our team with developing a nutritious fish feed formula and pelletizing machine capable of creating small, round, compact, and smooth fish food pellets.

Aquaponics System Installed in Kenyan School by The Invictus Initiative

The project parameters considered the economic and geographical constraints of our target audience in Kenya. The fish feed formula would need to be nutritionally viable and utilize local food sources. The pelletizing machine needed to be effective, inexpensive, easily operated and maintained, and built using locally sourced materials.

Our team approached the challenge with these constraints in mind. After considerable research, discussion, and evaluation, we selected an optimal fish feed formula and pelletizing machine. We then moved forward to create functioning prototypes.

In order to prototype and test the feed formula, we prepared the various raw ingredients and used an industrial disk pelletizer to create pellets from the mixture. The resulting pellets were tested for floating capabilities, sink time, and nutritional effectiveness.

The pelletizing machine was built using simple tools, which would be readily available to the Kenyan Villagers, and consisted of PVC, nuts and bolts, scrap parts, and a plastic 55 gallon drum. After finishing construction of the machine prototype, it was tested for effectiveness in creating viable fish pellets from the designed fish feed formula.

Given the nature of this project, both the finished formula and machine prototypes are extremely similar if not identical to what is anticipated to be the final product for the school in Kenya. Our team is extremely satisfied with the results from our testing, and we are confident that our designs meet and even surpass the given project parameters from The Invictus Initiative.

Wearable Technology: Smart Suit

20

Client(s): Kylen McClintock
Faculty Advisor: Robert Huehmer
Team Name: Team Supa Suit
Team Members: Nicholas Broucek, Brian Cox, Henry Dau, Dionysi Damaskopoulos, Nathan Pohl, Jackie Vasquez

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The startup company AirBeSpoke commissioned Team Supa Suit to design a smart suit that incorporates wearable technology into a men's suit. AirBeSpoke is a Colorado School of Mines startup dedicated to revolutionizing men’s clothing by providing an affordable, fitted suit to anywhere in the US much faster than the average tailor.

Suit image used by permission of AirBeSpoke

Our smart suit includes near field communication (NFC) tags, a medical quick response (QR) tag, radio-frequency identification (RFID) blocking fabric, a wireless phone charger, a microphone, and capacitive touch buttons. The NFC tags can be used to link to websites like a LinkedIn profile. The medical QR tag can be designed to provide information on any allergies, blood type and medical conditions to anyone who scans it. RFID blocking fabric is integrated into a pocket to keep your phone, wallet, and any other devices that use RFID from being remotely accessed by cyber criminals. The wireless phone charger can charge your phone in your pocket while you are walking around or while you are in a meeting. The microphone can be used to record voice memos straight to your phone. The capacitive touch buttons can be used to interact with your smartphone and can be programmed to do a custom action of your choice.

All of the electrical components are linked together using a microcontroller, which handles powering all these components and handling inputs. There is also be a companion Android application which will help the user operate their smart suit and interact with all the peripherals on the suit as well as allow the touch buttons and microphone to provide input to the smartphone. Team Supa Suit has developed a prototype smart suit and conducted safety and durability testing of the suit and its components. Additional work is being conducted to examine mass manufacturing of the smart suit electronic components.

Formula SAE Carbon Fiber Monocoque Challenge

21

Client: Greg Reback, CoorsTek
Faculty Advisor: Maria Carolina Payares-Asprino
Technical Consultants: Marc Griswold, Steelhead Composites
Team Name: Team Carbon Nation
Team Members: Ryan Belanger, Alec Bogenschutz, Casey DeRosa, Alex Flanagan, Collin Hall, Nicholas Novack, Edward Pancost

In 1981, McLaren Automotive revolutionized the racing and automotive industry with the first carbon fiber monocoque chassis. Since then, the monocoque chassis has become a popular solution for racing and high performance car chassis. With the availability of high performance processing and analysis, carbon fiber reinforced polymers (CFRPs) can be accurately modeled with minimum physical testing. With this technology, the design and analysis of a CFRP monocoque chassis is possible for a student team.

This team was tasked with designing and validating a CFRP monocoque chassis for the Colorado School of Mines Formula SAE team. A chassis was designed in SolidWorks and analyzed with Femap with NX Nastran. Once the chassis design met the requirements of the team and the competition rules, samples of carbon fiber were tested for their material properties to validate the FEA model analysis. The team will deliver a full engineering report and package, including manufacturing drawings and plans, for a future Mines Formula SAE team to use in construction.

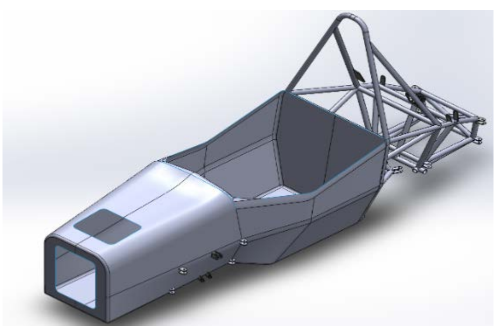


Figure 1: Chassis CAD Model

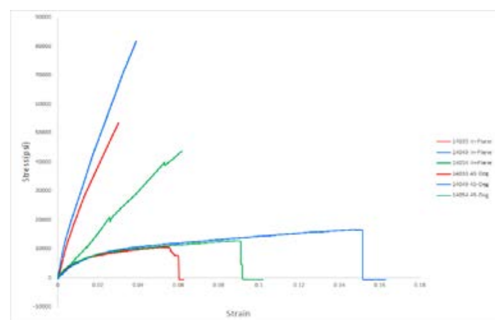


Figure 2: CFRP Stress-Strain Results

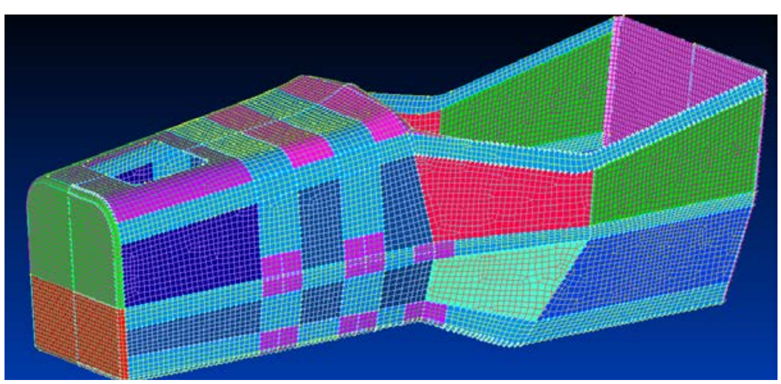
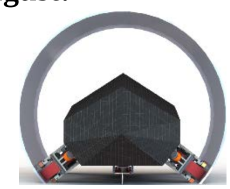


Figure 3: Meshed Chassis Model

SpaceX Hyperloop Pod Competition II 22

Client(s): Dr. Jeff Schowalter
Faculty Advisor: Dr. Kristine Csavina
Technical/Social Context Consultants: Dr. Robert Amaro, Prof. Jered Dean, Dr. Andrew Petruska
Team Name: Diggerloop
Team Members: Christian Grundfor, Zach Melphy, James Bloomfield, Ryan France, Michael Lanahan, Jacob Suter, Karl Grueschow, Braiden Olds, Jackie Knott, Jeremy Che, Austin Genger, Vince Koch, Will Marquis, Tim Walker

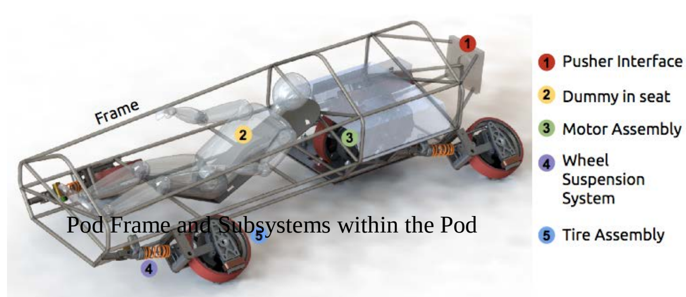
The SpaceX Hyperloop Pod Competition II challenges student teams from across the world to design a high speed transportation pod to carry a test-dummy on their test track in California. The only criterion for evaluation is the fastest speed of the pod with successful deceleration by the end of the 4150 ft competition track. **The DiggerLoop team advanced as one of 24 teams to the final competition weekend in Hawthrone, California in late August!**

Rendering of Pod Shell and Front View of Pod in Tube. Angled Wheels Provide Stability on Rail and within Tube.

Their current pod design consists of an AC motor with a drive wheel assembly for propulsion, friction and eddy current brakes for braking redundancy, and a complex angled wheel suspension system. The pod frame consists of AISI 4130 steel tubing and the shell material is carbon fiber sheets. Power is supplied to the pod by 7.4V, 8200 mAh LiPro RC car batteries that are located onboard the pod. The navigation system of our pod utilizes microcontrollers, photodiodes, accelerometers, and temperature sensors. This system ensures that our pod will stop safely before the end of the tube (or anywhere in the track in an emergency situation) and that our batteries will not overheat. The estimated maximum speed is currently 260 mph and the total weight is about 1070 lbf.

Team Diggerloop is excited to compete in the final competition in August and feels that there have been valuable lessons learned from taking on this challenging endeavor, including: managing large projects (five sub-systems in the pod design), working on large teams, solving problems on the fly, adapting to criteria and changes, and finally, communicating design changes across subsystem teams. The team is very thankful for the opportunity to work on this challenging and meaningful project and is confident that these lessons will prove extremely valuable in future careers.



Pod Frame and Subsystems within the Pod

Rooney Road Solar Challenge

Client: Theresa Worsham, City of Golden
Faculty Advisor: Dr. Jeff Holley
Consultants: Dr. Ammerman & Dr. P.K.Sen
Team Name: Rooney Bin
Team Members: Jordan Brothers, Robin Hoover, Jake Kunugi, Cassie Kraft, Keaton Looney, Dustin Rhodes, and Nikko Sandoval

The primary goal for this project is to design a 10 acre solar garden on top of a capped landfill at the Rooney Road landfill site in Golden, CO. The solar garden will be owned by the City of Golden and provide energy to local residents via an energy subscription service. Team Rooney Bin designed a system with a goal of 2 MW power output in mind using ballast-mounted solar panels.

Aerial drone photography of Rooney Road site in Golden, CO taken by Dustin Rhodes.

First and foremost, Team Rooney Bin catered to the needs of the City of Golden by designing a project that will meet their needs and be within the unique constraints of building on a landfill. In addition, team Rooney Bin created their design according to the standards and specifications laid out by the Jefferson County engineers and industry standards such as IEEE, NEC and ENVISION. Furthermore, Team Rooney Bin consulted with a local solar panel installation business (Buglet), the landfill project engineering contractors (Souder Miller), and the local utility provider (Xcel Energy) to use industry experience and guidelines with the implementation of this design.

Additionally, it is crucial to understand that the implementation of this design will not begin until after November 2017 after the vote to rezone Rooney Road Park for renewable energy use is passed by the City of Golden. Lastly, Team Rooney Bin is excited to be the first projected ENVISION (a sustainability grading scale for infrastructure projects similar to LEED) project in Colorado and the first purely solar project in the United States that is planning to implement these environmental grading criteria.

2017 ASCE Concrete Canoe

24

Client(s): Chris Bottoms, Kiewit
Faculty Advisor: Branden Gonzales
Technical/Social Context Consultants: Dr. Panos Kiousis, Kathleen Smits, Jan Smits, Andres Guerra, Kristoph Kinzli, Kevin Sobczak, Jeff Holley
Team Name: The Abominable Rowmen
Team Members: Peyton Gibson, Maito Okamoto, Jon Chestnut, Melanie Stephenson, Aaron Graham, J.D. Kohl, Jorge Rodriguez, Grant Meehan, Marissa Padgett, Jack Henderson, Nick Chavez

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In the fall of 2016, a breaking news story shook the scientific community. Two spelunkers had gone missing during an excursion to an uncharted ice cave. One of their few recovered possessions was a camera with a photograph of a large, unidentifiable creature. When a group of young engineers from Colorado School of Mines (CSM) set out to pursue the elusive abominable snowman, the engineering campus became the stage of a tumultuous debate over the existence of such a creature. However, the group continued planning their journey, but found the glacial entrances to the caves were too treacherous for a motorboat or single-rider kayak. The team needed a boat that was strong enough to withstand an abominable snowman attack, maneuver through icy waters, and fit all four members. Only one type of vessel would ensure that they would make it back alive from this expedition: a concrete canoe. Thus, the 2016-17 CSM concrete canoe team, *The Abominable Rowmen*, and their canoe, *Let it Row*, were born and the hunt was on.

Figure 3: Casting of the Canoe

Since 1971, a competition has been hosted across the U.S. with a unique problem statement; make concrete float. In 1987, the American Society of Civil Engineers formally established the first National Concrete Canoe Competition (NCCC), with the first set of rules to go with it. Since then, the rules of the NCCC have evolved from a few bullet points into a complex specification book. CSM competes in the Rocky Mountain Student Conference, where its last three teams have placed 8^{th}, 4^{th}, and 4^{th} overall, respectively. The 2017 team aims to improve upon those standings and place within the top two teams to advance to the National Competition, hosted by our own university this summer.

To reach Nationals, our team has included several new and innovative features into *Let It Row*: two completely unique concrete mixes to increase strength, workability, and finishing; new construction techniques and quality control processes during mold construction to achieve a better alignment and smoother finish; a regular paddling practice schedule; detailed casting and finishing plans; and a detailed task-oriented project schedule with a conservative amount of float to accommodate unforeseen delays or accidents. The team's innovative mix design incorporates a state-of-the-art admixture, carbon nanotubes, that more than doubled past team's tensile strength and improved flexural strength by 150%, making the canoe strong enough to survive impact to any glaciers or abominable snowman in its way.

2017 ASCE/AISC Steel Bridge Competition – Licensed to Steel

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Client(s): Ben Seling, Kiewit
Faculty Advisor: Becky Dimond
Technical/Social Context Consultants: Joe Crocker, Jeff Holley, Dave Genova
Team Name: Licensed to Steel
Team Members: Kali Randall, Dallas McCoy, Nick Johnson, Steven Stella, Angela Eickelman, David Mboko

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This project involved designing and fabricating a steel bridge in accordance with the ASCE/AISC NSSBC competition rules. The 2017 competition is hosted by Oregon State University and thus is based on the Luckiamute River. We were challenged to design and build a bridge that not only meets the required size and load constraints, but is economically and environmentally feasible for this location. As this is a competition, made our design in such a way that maximized the scoring potential. Areas under critical considerations include serviceability, construction cost and duration, material cost, and esthetics. The AISC/ASCE Student Steel Bridge Competition challenges students to apply theories learned to real world applications. The final contract will be awarded to the school that best addresses the challenges and requirements of this project. The progression of the competition started with Springfest. The winner of the two teams from CSM then progressed to Regionals, the ASCE Rocky Mountain Student Conference, and then the performance there determined the team's participation in the National Competition in Corvallis, OR the last weekend of May. We decided to utilize a half through arch design for our bridge as shown in Figure 1, which is different than the design used by last year's team. We went with this design because it had not been done in competition before, and the theory behind the design was strong for the constraints at hand. There were many rules we had to take into consideration in order to make this design work for competition. The main concerns for scoring of the competition are the lateral and vertical deflection of the bridge, construction speed, and total weight of the bridge. We also need to determine the construction economy and take environmental effects into consideration.

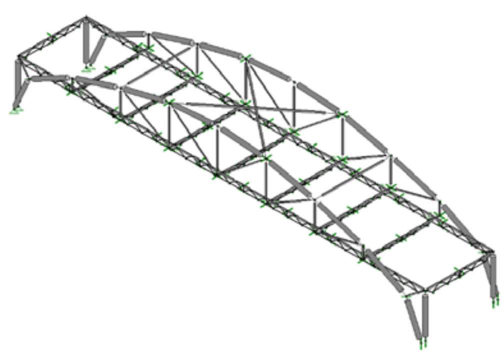

Figure 1: Isometric View of Bridge

2017 ASCE/AISC Steel Bridge Competition – Overworked & Underpaid

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Client(s): Ben Selig, Kiewit
Faculty Advisor: Brandon Gonzalez
Technical/Social Context Consultants: Joe Crocker, Andres Guerra, Jeffrey Holley, Dave Genova
Team Name: Overworked and Unpaid
Team Members: Dominick Steel, Levi Gottsponer, Michael Kelso, Leighton Moreland, Lupe Garza, Jessica Weyand

The ASCE/AISC National Student Steel Bridge Competition (NSSBS) proposed the construction of a bridge to be designed and fabricated by university students across the country. The basic requirements for the bridge were that it must span twenty-one feet and cover a seven-foot river. During construction, the river cannot be crossed by any builder, tool or bridge component or face construction penalties. The bridge can be no wider or taller than five-feet.

At the competitions, the team with the lowest overall cost is declared the winner. The total cost is a sum of the construction cost and structural cost. These costs are functions of prices associated with weight, construction time, number of builders, violations, and aggregate deflection. The bridge must be designed to minimize the cost of each of these components.

Colorado School of Mines has participated in this competition for many years and had much success in the 2016 Competition (the team moved on the Nationals). Based on their success the 2017 team built off of the design from last year to optimize the design. This year, with the sponsorship of Kiewit, Overbuilt and Unpaid will represent the university at the regional competition on April 6-8, 2017 at the University of Utah. The final design is shown below in Figure 1. The design features an overhead arch truss with decking support – which is very similar to last year's design. The main differences were simplified connections, a round cross section on the member sections, and simplified interface between the vertical bracing and the bridge decking. Overall, this design was selected because it had the lowest predicted deflections for the worst case loading as defined by the competition rules. The predictions for this bridge is a weight of 200 pounds (comparable to last year's bridge), and a vertical deflection of half an inch (about half of last year's deflection).

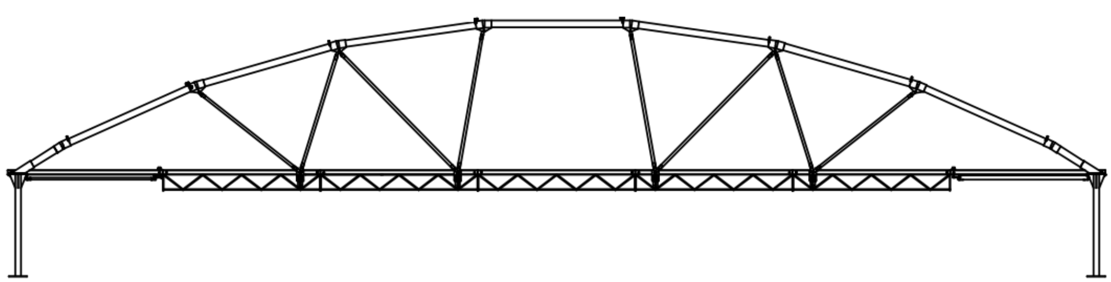

Figure 1: Side View of the Bridge

2017 SPE Drillbotics Competition

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Client(s): Alfred Eustes and Jorge Sampaio
Faculty Advisor: Maria Carolina Payares-Asprino
Technical/Social Context Consultants: Buddy Haun
Team Name: The Molebots
Team Members: Alex Albright, Nick Collins, Khoa Le, Zaharim Hashim, Reed Baker

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The 2017 Drillbotics Competition is held by the Drilling Systems Automation Technical Section (DSATS) of the Society of Petroleum Engineers (SPE), and was created to encourage innovation in drilling automation. The competition is to create a drilling rig that that is capable of drilling a vertical hole in an unknown rock sample without any human control. The main limitation in the rig design is the drillstring, which must be thin aluminum tube that is susceptible to buckling. The judging committee has selected seven teams from schools around the globe to compete this spring, and will judge the teams based upon performance, wellbore quality, data manipulation, creativity, engineering, construction, and cost management.

Before creating an autonomous drilling rig, our team must first create the rig itself. We designed and built the key components that make up a drilling rig: the frame, drawworks system, traveling block, derrick, and fluid circulation system. We then moved on to instrumenting the rig to collect a wide variety of measurements to be utilized in its control. Parameters such as weight on bit, drillstring torque, top drive speed, and position are all measured and used to optimize drilling. We also have an inertial measurement unit which will be placed into our bottom hole assembly to measure acceleration, vibration and inclination. With the sensors in place, we moved on to the control system, which uses feedback from the sensors to decide how to control the system. In order to autonomously find the fastest operating parameters, we implemented an optimization algorithm that tests different operation points and converges on an optimal set. Finally, we have placed all pertinent data onto a user friendly graphical interface that organizes data in a way that allows the operator to carefully monitor all of the drilling parameters and visualize the operation.

NASA Robotic Mining Competition

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Client(s): NASA, Dr. Angel Abbud-Madrid
Faculty Advisor: Dr. Randy Haupt
Technical/Social Context Consultants: Dr. Ozkan Celik
Team Name: Blasterbotica
Team Members: Grant Jacobsen, Andrew Petersen, Marcus Turner, Grayson Sander-Olhoeft, Nick Attarian, David Vadnais, James Henry, Connor Holmes, McKyler Korth, Hayley Lansing, Michael Bowman

Recent missions to Mars have indicated large amounts of water both in ice form near higher latitudes as well as hydrated minerals. To successfully colonize the planet, these forms of water need to be extracted for in-situ resource utilization, or for "living off the land." The minerals, better known as regolith, must be mined and then processed into a liquid where it can be used for human consumption, agriculture, rocket propellant, or other various needs. NASA decided to get the help of universities around the nation with this problem by holding a competition.

The NASA Robotic Mining Competition requires teams to design and construct a mining robot that can autonomously cross the simulated surface of Mars. Once the Martian surface has been crossed the robot must mine the regolith, or the ice simulant which has been placed 30 cm below the surface. The robot must be less than 80 kg, fit in a 1.5x0.75x0.75 meter space before deployment, and use minimal bandwidth. Other factors that teams are scored on include dust tolerance, dust control, and power requirements. The categories scoring categories are, on-site mining, a systems engineering paper, outreach project report, social media/public engagement, and a presentation/demonstration.

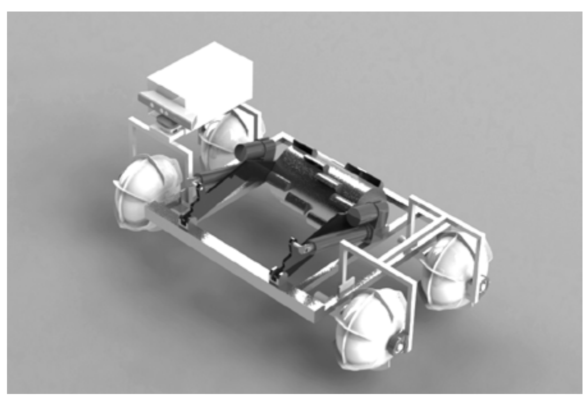
Figure 1: Solidworks model of the final design

Our team decided to build upon the design from the previous year, focusing on improving the areas that were lacking, while maintaining a stable baseline to work from. Our key focus was on implementing a fully autonomous robot, and new simplified digging system. We are using a bucket drum design for our digging system, which removes unnecessary system complexity and allows for reliable digging. The entire new digging system relies on only two moving parts, which limits the points of failure, and the complexity of the control code. Our autonomous system utilizes data from two cameras and an onboard inertial measurement unit to determine the robot's location within the playing field, and uses localized simultaneous localization and mapping, to navigate the arena.

We would like to thank all the companies that helped us this year, either through technical consulting, or through financial support. Thank you to Newmont Mining, Bechtel, Lockheed Martin, the Center for Space Resources and both the Electrical and Mechanical Departments at the Colorado School of Mines!

SAE Baja Competition

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Client: Dr. Robert Amaro
Faculty Advisor: Donna Bodeau
Technical/Social Context Consultant: Dr. Robert Amaro
Team Name: CSM Baja Team
Team Members: Christopher Britschge, Adam Cameron, Russell Carlson-Stadler, Arthur Cooper, Joshua Gruener, David Harper, Mark Huber, Drew Lange, Edwin Nicholas, Trevor Reed, Stephen Rocheleau, Cameron Vogel

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The 2017 CSM Baja team is a group of 12 mechanical engineers competing in the SAE Baja Competition in Kansas. Each year, the Society of Automotive Engineers (SAE) hosts a challenge to design and build a single seat, off road vehicle to compete in four events. The events are set up to test the vehicle's reliability, maneuverability, capability and ergonomics. They include a sled pull, a maneuverability test, an acceleration test, and a suspension test. The competition also includes a sales presentation to evaluate the marketability of the car and a four- to six-hour endurance race. The competition occurs at the end of May in Pittsburg, Kansas. Our goal for the competition this year is to place in the top 25% of the competitors.

The SAE Baja Competition requires all teams to use a standard engine provided by Briggs and Stratton. This means that we had to figure out other ways to make the car more competitive. The most notable of which are making the car lighter and designing a high performance suspension system. We took many measures to shed weight from the car, the most significant of which are the usage of 4130 Steel Pipe for the chassis and the usage of Aluminum for the body panels and firewall. We also made the chassis very compact but still kept adequate space in the cockpit for driver comfort. The suspension system we designed is similar to that on off-road racers and trophy trucks. We also included highly adjustable shocks in our design allowing the user to tune the suspension for different terrains. With those and the many other measures we took to make the best car possible, we are hopeful that we will place in the top 25% of the competition.

Shell Eco-Marathon Competition

30

Client(s): Kyle Hilberg
Faculty Advisor: Bill Sekulic
Technical Consultants: Prof. Jered Dean, Prof. Robert Amaro
Team Name: 2 Efficient 2 Furious
Team Members: C. J. Pfutzner, Josh Wisda, Austin Hutchison, Kyle Cramsey, Kyle Whittle, Josh Morsicato, Jibreel Frawan, Ryan Hunt, Zach Cosper, Kevin Lannen, Zach Swanson

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In a world shaped by strong globalization forces and increasingly interconnected international economic markets, the demand for transportation and energy solutions is growing. The Shell Eco-marathon competition, sponsored by Shell Oil, is an event designed to unite young engineers with some of these future challenges. Teams of students are tasked with building an ultra-energy-efficient electric vehicle to compete on an urban circuit against other vehicles and teams from around the world.

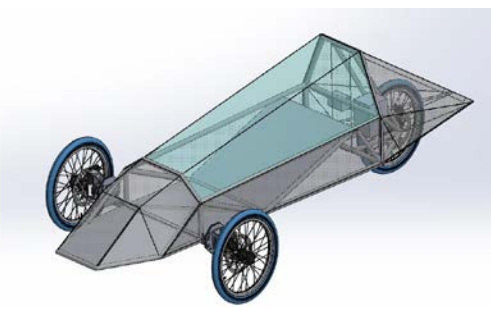

Figure 4. 3D Vehicle Model

This project involves a concerted, interdisciplinary effort of 11 mechanical and electrical engineers working to design and build a safe, efficient, and lightweight electric vehicle which will be driven in competition in Detroit by one of our team members. Shell provides stringent requirements governing necessary safety components on-board the vehicle, but the remainder of the design is left up to the team. Our final design incorporates a lightweight aluminum frame, an aircraft-grade molded body, tactile steering and braking systems, a high-efficiency dual-motor drive train, a purpose-built motor controller stage, and a lithium-ion battery pack (with a battery management system). In addition, a DAQ monitoring system on-board the vehicle actively monitors the performance of the vehicle during competition and wirelessly uploads efficiency data to a software cloud for additional analysis and insights towards design improvements.

In preliminary analysis and testing, it became clear that weight and aerodynamic drag are the predominant determinants of the performance of the vehicle during competition. To that end, mechanical design decisions became necessarily justified by the optimization of these two objectives. On the electrical side, efficient operation of a brushless DC motor was the single most important goal. Our two-motor drivetrain design utilizes a software-defined throttle that matches power demand and wheel speed against motor efficiency curves to provide maximal efficiency at a wide range of operating conditions. In April, our driver and team will efficiently and safely use this car in the Shell Eco-marathon.

Air Reverse Circulation Ice Drill Challenge

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Client(s):	Jay Johnson, Chris Gibson, Ice Drilling Design and Operations
Faculty Advisor:	Robert Reeves
Technical Consultants:	Bill Eustes
Team Name:	Team Yeti
Team Members:	Cameron Commerford, Baxter Gully, Chayce Moniz, Joseph Pauza, Abby Lestina

Ice Drilling Design and Operations (IDDO) is tasked with providing engineering design support for new drilling systems as well as the operation and maintenance of existing drill systems. Among these projects is a Rapid Air Movement (RAM) drill that is operating in Antarctica. IDDO tasked Team Yeti with modifying the RAM drill by designing an Air Reverse Circulation (ARC) drill downhole crossover system in order to reach deeper drilling depths. Currently, the RAM drill performs as desired for most ice drilling locations. However, for regions where the ice turns to firn (compacted porous ice) the RAM drill is unable to achieve the desired depths as the firn allows too much air to escape. This loss of air pressure results in an inability for the RAM drill to operate effectively at these depths in these areas. The crossover design will prevent this pressure loss to the firn by recirculating the air back into an enclosed pipe system.

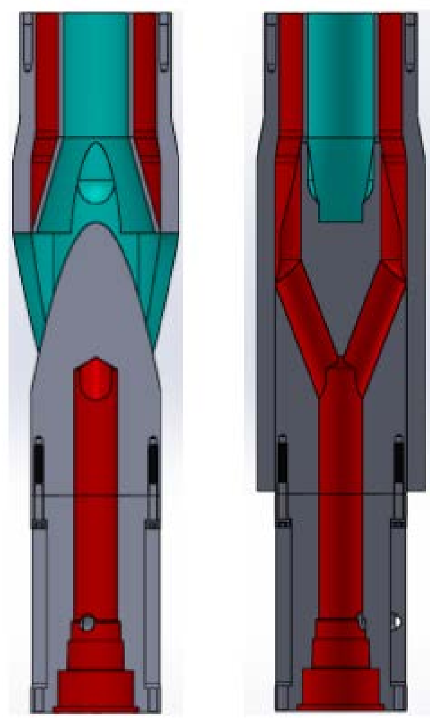

FIGURE 1: CAD MODEL OF CROSSOVER ASSEMBLY

The project goals include determining the air pressure and flow requirements to achieve depth down to 200 meters, determining the best tube diameters for the drill, evaluating lightweight drill options, and designing the complete down-hole drill assembly. Design of the drill includes the cutter head, air motors, and drill rod tubing. The required design will ensure all cuttings clear the bore by minimizing air pressure losses within the drill assembly and optimizing the cutter head aerodynamics to circulate cuttings

The crossover design will expand the scope of drilling projects accomplishable by IDDO in extreme, artic conditions and help continue to push the boundaries of what is possible when performing ice drilling operations. Figure 1 is the Solidworks model of the crossover assembly with the lines to drill head (Red) and chip circulation lines to the Surface (Blue).

Alternative Framing Connectors

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Client(s): Lizzie Collins, S.E., Build Change
Faculty Advisor: Rebecca Dimond, P.E.
Team Name: Team CNXS
Team Members: Brent Kehoe, Adam Hall, Dane Arakawa, Caleb Fiebig, Claire Mahoney, Emily Echelberger

Fig. 1 Metal Strap (Solidworks by A. Hall)

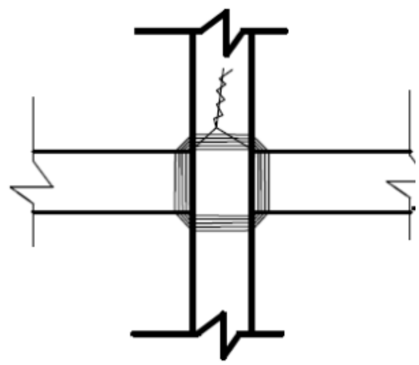

Fig. 2 Wire Lashing (Courtesy of Shelter Cluster)

Build Change is a nonprofit organization dedicated to reducing deaths, injuries, and economic losses caused by housing and school collapses due to earthquakes and hurricanes in developing nations. Connectors, such as those used in wall to roof or roof-to-roof connections, are one of the most vulnerable parts of buildings in disaster-prone areas. Build Change has developed several connections to be implemented in these countries, but there is little data on their failure modes and ultimate strength. Team CXNS worked with Build Change to evaluate two of these connections and provide recommendations on safe implementation in the field.

The principal constraints of the project are based on building conditions in Build Change's target countries: roofing connectors must be easily constructible by hand, without the use of any electrical equipment; the connections must be fabricated with materials that are readily available; and the implementation of the designs must be clear to ensure that they are constructed as intended in the field.

Team CXNS has worked to evaluate two roof-to-roof connections for strength and constructability: a metal strap for truss to purlin connections (Figure 1) and a wire lashing for rafter to purlin connections (Figure 2). Team CXNS has determined the strength and failure modes of these connections, and has compiled this information into a set of recommendations for their safe and effective use.

Team CXNS has provided Build Change with ample strength information about their current roofing connection designs so the nonprofit can feel confident when implementing these connections in the field. In addition to research on the existing designs, Team CXNS recommended modifications to increase the strength of these connections. This combination of data and design will allow Build Change to be confident in the safety of the housing they construct.

Cedarville Rancheria Geothermal End Uses Challenge

33

Client(s): Daniel Kaim and Bobbie Wells, Division of Energy and Mineral Development (DEMD)
Faculty Advisor: Rebecca Dimond, P.E.
Technical/Social Context Consultants: Dr. Nicole Smith, Dr. Masami Nakagawa
Team Name: GEOPamaka
Team Members: Kekahu Aluli, Mason Haycock, Becky Reeve, Travis Terrell Ramos

The objective of GEOPamaka was to create end use system designs for an existing geothermal well for the Northern Paiute Indian Tribe in Cedarville, California, under the guidance of the Department of Energy and Mineral Development (DEMD). The work performed by GEOPamaka include:

- Detailing end use designs for the existing geothermal well
- Providing an economic analysis for each final design
- Understanding overall social implications of the project

Figure 1: Wellbore Render

The primary goal of this project was to highlight the socio-economic benefit for the tribe through engineering means. Through stakeholder engagement practices, GEOPamaka was able to sit down and listen to the needs and wants of tribal members. As per their recommendation, the proposed final designs feature geothermal heating of the tribe's community owned convenience store and gas station, Rabbit Traxx, and a new greenhouse design. Both designs include economic feasibility studies, as well as supporting calculations for total heating requirements, heat and power losses through the piping network, differing pipe diameters, and a range of geothermal flow rates and temperatures. With this knowledge, the tribe can select the optimal design once the sustainable yield of the well is known. More importantly, the tribe has been included in each iteration of the design process, which translates to an important step in sustainability and responsible development.

The wellbore schematic render seen in Figure 1, is a visual representation of the geothermal well casings and relative depths of production. The Rabbit Traxx design implements the use of an existing geothermal heating system to provide heat to the building during specified hours. The greenhouse design provides a produce source for the tribe and the potential for revenue generation. Figure 3 shows a rendered model of the greenhouse design. The process diagram for the entire proposed system can be seen in Figure 2 below.

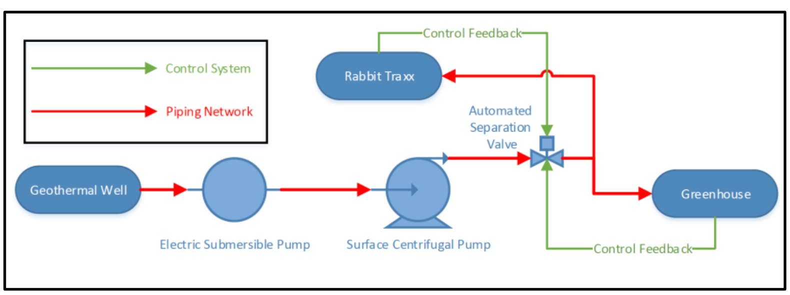

Figure 2: Process Diagram

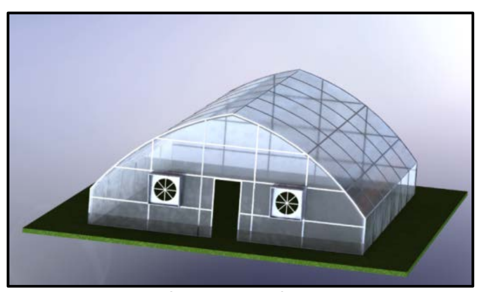

Figure 3: Greenhouse Render

Community Connection Across I-70

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Client(s): Mr. Steve Glueck, City of Golden
Faculty Advisor: Prof. Jeff Holley
Technical/Social Context Consultants: Prof. Jeff Holley
Team Name: Golden Connection
Team Members: Jackie English, Chace Malone, Adele McKenna, Angus Campbell, Madi Northrup

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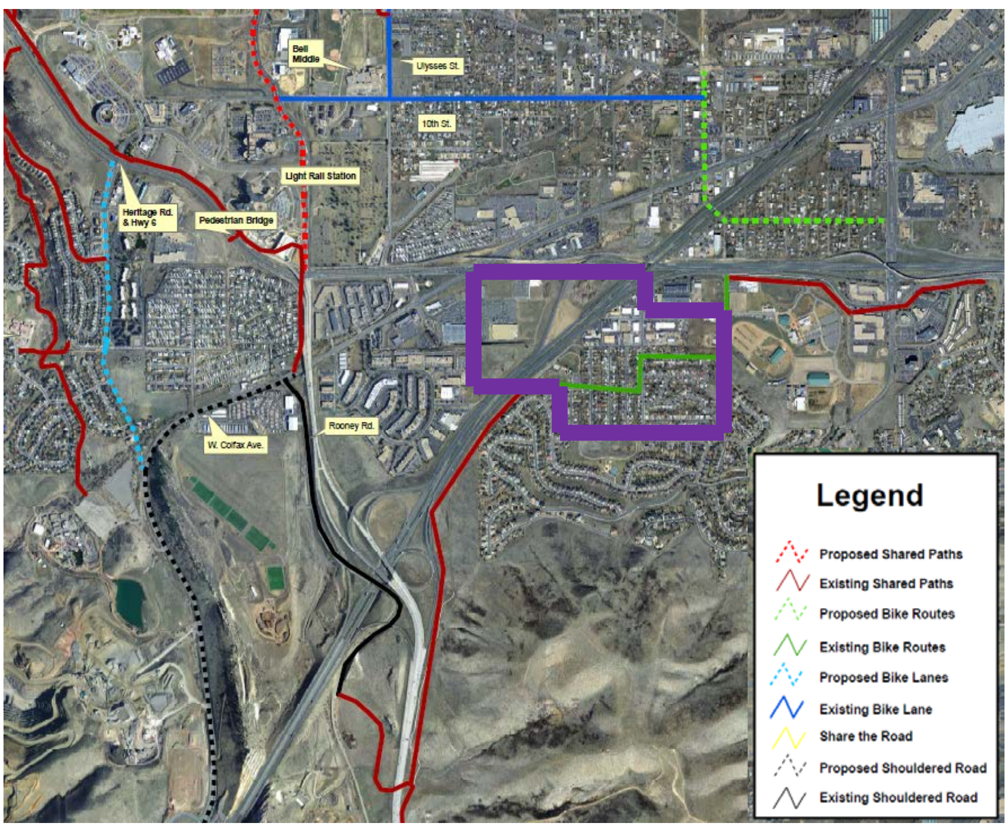
The Community Connection Across I-70 project aims to determine the possibility and feasibility of reconnecting the City of Golden and a small community south of Interstate 70. This small community, named Golden Heights, was isolated from the rest of the City of Golden when Interstate 70 was built. As such, the City of Golden has asked our team to establish the need for a connection and examine different connection options in order to determine the best and most feasible option. Our team has made the creation of easy accessibility to many of the walking and bicycle paths that exist in the City of Golden the main priority of the project. We have looked into different forms of connections, such as a bridge or tunnel across Interstate 70 along with different types of transportation, such as pedestrian or vehicle traffic. The Golden Heights community is outlined on the vicinity map below, using a heavy-weighted purple line. This map also includes both existing and proposed walking and bicycle paths in the City of Golden.



Cuttings Volume Measurement Challenge

Client(s): John Macpherson, Baker Hughes, Inc.
Faculty Advisor: Robert Reeves
Technical/Social Context Consultants: Dr. Alfred Eustes
Team Name: The Notorious ENG Senior Design Team
Team Members: Marcus Banister, Marcos Hernandez Rodriguez, Caleb Kimball, Joseph Stewart

Introduction

The Notorious ENG Senior Design Team developed a proof of concept method for Baker Hughes Inc. to measure the volume of the drill cuttings exiting a wellbore per unit time by utilizing visual analysis. The designed system utilizes MATLAB and edge detection techniques to determine the area of rock particles in a 2D image, and then applies a volumetric conversion to approximate the volume of the rock particles.

Client Needs

Baker Hughes Inc. requested a system that stresses safety as the primary goal of the system. A relatively inexpensive system that can implemented on many rigs was also requested by the client. The technical requirements that the client requested are a measurement accuracy within five percent from actual cuttings volume, measurement latency under one minute, the capability to measure all typical sizes of rock cuttings, and a desired lifespan of 3-5 years.

Solution

Due to the request of Baker Hughes Inc. to develop a proof of concept method, the visual analysis system using a single image capture was determined to be the best solution. This is because of the robust nature of the image capture process, as well as the limitations created by the slurry mixture that enters the shale shaker during the drilling process. Implemented at the end of the shale shaker, the system captures rock particles after they have been separated from the mud mixture created during the drilling process. This allows for better image quality and increases the accuracy of the system. The image is then analyzed using MATLAB and the volume is calculated based upon shaker screen and drilling speed.

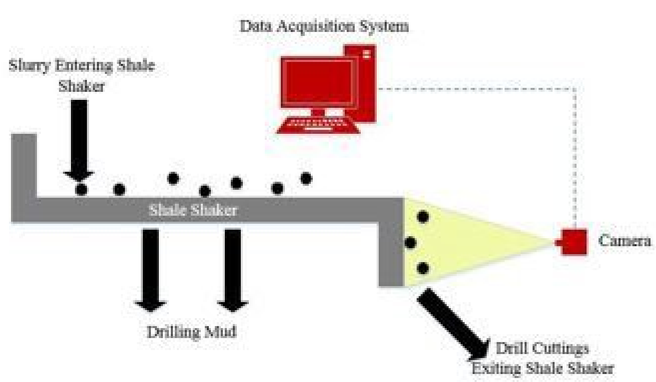


Figure 1: Conceptual diagram of Image Analysis System

DA Water Tower Challenge

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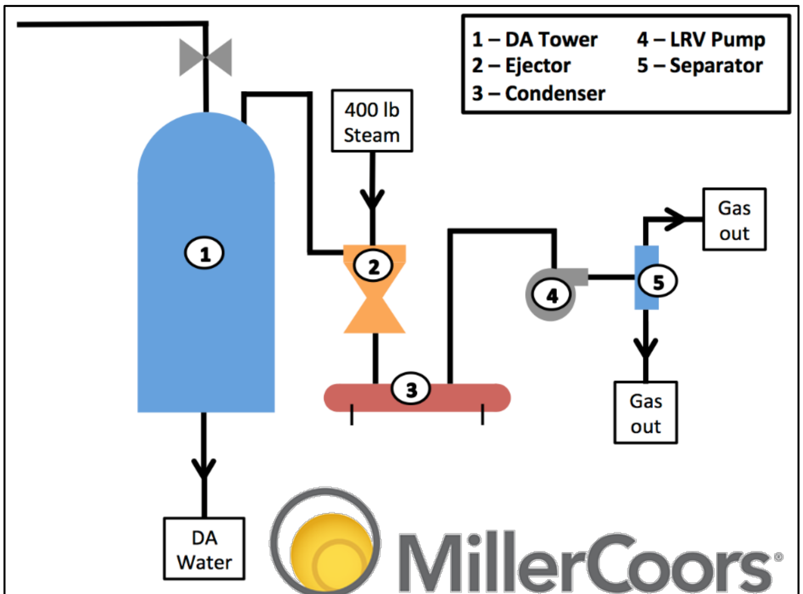
Client(s): Greg Miller, MillerCoors
Faculty Advisor: Robert Huehmer
Technical/Social Context Consultants: Tracy Gardner, Robert Huehmer
Team Name: CSM EngiBEERing
Team Members: Chris DeAngelis, Cody Marvel, Bill Mitchell, Evan Person, Taylor Poynor, Tait Priser

Introduction

In order to produce beer with minimal residual taste, MillerCoors uses ozone as a water disinfectant rather than chlorine. However, the presence of excess oxygen encourages microbial growth in the water, which can also affect the taste of the beer. In order to avoid this, MillerCoors utilizes a vacuum deaeration (DA) system so as to remove oxygen to levels within MillerCoors' standards. This system consists of five separate DA water towers that vary in size and operational conditions. Currently, the MillerCoors DA system is not performing at its intended design capacities. Team CSM EngiBEERing, therefore, has been tasked with identifying the current inefficiencies, formulating a plan to correct these inefficiencies, and finally to design upgrades to the current DA system that will reduce operational costs while optimizing the system's functionality.



Schematic of one of the original vacuum DA towers

Solution

The first step of the project was to understand and learn how the system works and compare that to how it is intended to work, therefore allowing potential problem areas to be identified. The team studied theory of the deaeration system, including the hybrid vacuum system, packed tower components, and system controls. Based on created troubleshooting matrices the team worked with MillerCoors to optimize the functionality of one tower back to original operating conditions. This helped the team identify issues and begin the design process with the goal of improving the system functionality. The detailed system improvement design produced by the team outlined a new vacuum system which utilizes two vacuum pumps for maintenance simplicity and a recirculation system that will improve operational control. This will augment the work to return the system to operating conditions and will allow MillerCoors to achieve more functionality than ever before.

Digital Shower Valve Challenge

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Client(s): Chris Cone, Traxion
Faculty Advisor: William Finch
Team Name: BACOG
Team Members: Michael Ennis, Aaron Zahn, Brandt Theander, Brayton Saunders, Alberto Dominguez, Caitlin Neuheardt

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According to the EPA's research, the average shower length in the United States is 8 minutes long and uses 18 gallons of water. An apartment building that holds one hundred people would go through 650,000 gallons of water per year if every individual took one shower per day. Taking into account water, sewage, and energy costs this would amount to $17,500 per year on average. The purpose of this project is to save money by reducing shower costs.

In order to accomplish these savings, the team designed and built digital shower valve system. It consists of an electrically actuated valve as well as a digital user interface. The digital interface allows the user to set their desired temperature, and provides a means to present the user with usage feedback. The feedback is designed to make the user aware of the time and utility consumption of their shower, which in turn leads to shorter showers. The system is able to significantly reduce behavioral waste, such warming the shower too long or staying in longer than needed. The team currently holds a US Provisional Patent for the unique control methods and data collection aspects of the shower system.

Dynamic Automotive Wheel/Tire Test Machine Challenge

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Client(s): Paul Brayford
Faculty Advisor: Dr. Carolina Payares-Asprino
Technical/Social Context Consultants: Dr. Robert Amaro
Team Name: Get a Grip Engineering
Team Members: Jake Albers, Cameron Stebral, Benjamin Smiley, Jeremy Benson, Kyle Gandee

The Dynamic Automotive Wheel/Tire Test Machine Challenge is a multi-year project with the goal of designing a device unlike any other in the world. There is currently no effective way to test wheel and tire combinations to failure. Having a device that could simulate potholes, curbs, heavy cornering, and other automotive hazards/conditions could lead to huge developments in the automotive and materials industry. Designing new wheels and tires to survive harsh road conditions has benefits from military to commercial to individual applications. The machine must be able to accommodate a wide variety of wheels, based on size and material, in order for it to be used effectively.

The challenge to Get a Grip Engineering was to design the suspension system and robotic interface of the machine, seen in Figure 1 below. A previous team designed the solution for the road surface simulator, how the wheels would be tested hitting bumps and holes. In order to have successful and effective tests, the machine must simulate a vehicle and its suspension. A robot will be used to push the suspension system and wheel into the road surface. The suspension must be durable enough to survive tens of thousands of tests, ensuring that the wheel/tire fails before the suspension. Get a Grip Engineering started with calculations done by hand to get initial dimensions of the parts to be designed, including the control arms. Next came a comprehensive design and analysis of the suspension and robotic interface, including many machine design principles such as fatigue and frequency analysis. The project solution includes a universal hub that can use many different bolt patterns, fulfilling the modular requirement of the client. Get a Grip Engineering greatly enjoyed the challenges that the project had. It brought together many of the skills we have learned in various classes in a setting we were all passionate about.

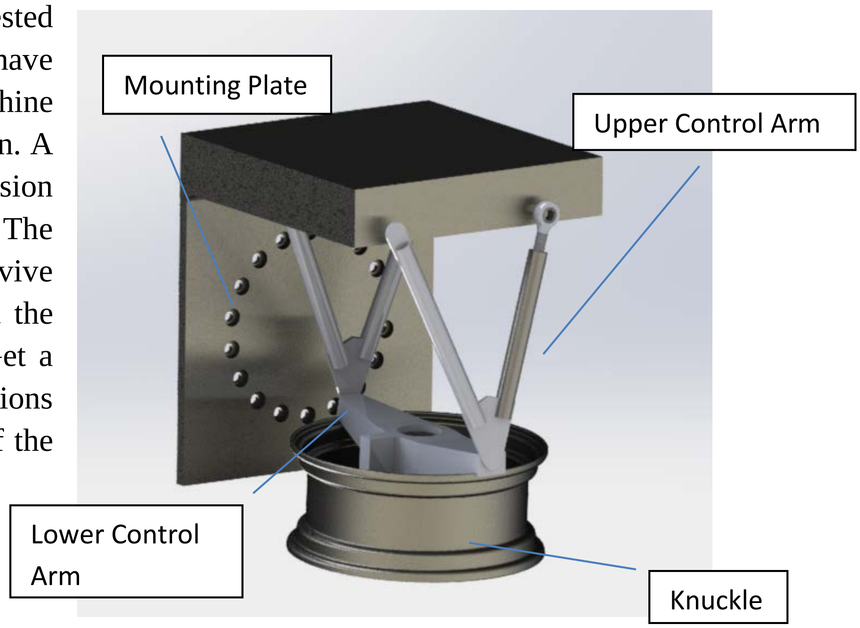

Figure 1: Suspension Assembly w/ mounting plate. Control arms to support wheel are connected to the plate at the top and the knuckle at the bottom.

Educational Model of the Goosenecks

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Client(s): Jerry Zink
Faculty Advisor: Dr. Yitz William Finch
Technical/Social Context Consultants: Dr. Leslie Wood
Team Name: Team Goosenecks
Team Members: Alejandro Galvan, Austin Saunders, Sydney Slouka, Laura Tyree, Erin Wadekamper, and Amy Young

The Educational Model of the Goosenecks is a project that will be designed and constructed for the Four Corners School Discovery Center in Monticello, Utah. The educational model will be designed to educate users of all ages on how the meanders of the San Juan River created the famous Goosenecks. The model will provide an interactive experience for users of all ages but will be focused for younger users ages 5-10. The model utilizes water flow to erode sand-like plastic beads and reveal a model of the Goosenecks. This mimics how river meandering caused extreme erosion that resulted in the Gooseneck formation. The user will be able to interact with the model in three different ways: controlling the water level with a cranking mechanism, altering the flow produced by a pump with a knob control, and ability to play with the sand-like plastic beads. The model will also come with a display board that will explain and describe in detail how the Goosenecks and other formations were formed. The goal of this project is to educate users on the following learning objectives:

- Demonstrate how the helical flow of rivers causes river meanders and how it relates to the tea leaf phenomena.
- Show how the Goosenecks are created through a process.
- Illustrate how other geological formations can be formed.

The importance of this project is to provide geological knowledge because many people are unaware of how the Goosenecks were formed.

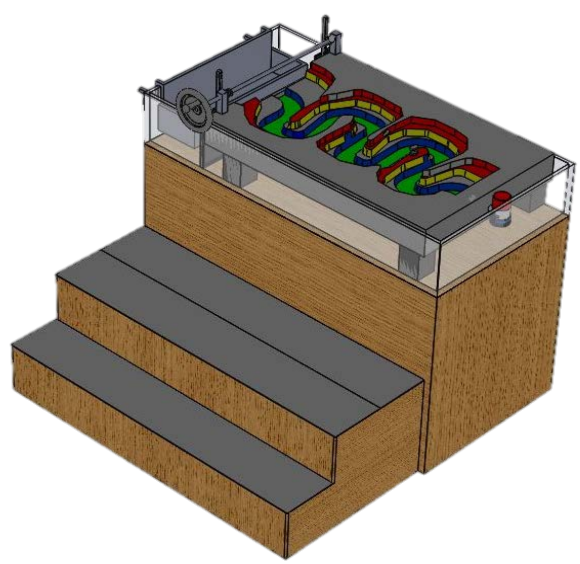

Figure 1. SolidWorks drawing of the design of the educational model

Embedded Antennas Challenge

40

Client(s): Jake Saur and Tracy Copp, Ball Aerospace
Faculty Advisor: Randy Haupt
Team Name: anTEAMa
Team Members: Sean Dempsey, Timothy Lyne, Ashley Macumber, Stephen Newton, Evan Shigaya, Michelle Teramura, Josh Westerlind

The purpose of the Embedded Antennas Challenge is to create a proof of concept for a method of 3D printing custom antenna designs at low cost. Antenna design is a limiting factor in the capabilities of many RF (Radio Frequency) systems. Custom-designed antennas can provide better performance, but are relatively expensive to manufacture. Additive manufacturing could provide a less expensive option for low-volume custom antenna designs. The Embedded Antennas Challenge includes creating a plan for manufacturing, designing a sample patch antenna to print, and finally, printing and testing the sample antenna.

To model the sample patch antenna, the team used the HFSS (High Frequency Structural Simulator) modeling program. HFSS is a simulation package that allowed the team to design and optimize the GPS antenna for this project. The program also provides simulated data on the patch antenna that could be compared to experimental data. After the antenna is printed, range tests are performed to test various parameters including the Voltage Standing Wave Ratio and the Axial Ratio. After obtaining test range data, this new data is applied to the HFSS model. This process has several iterations.

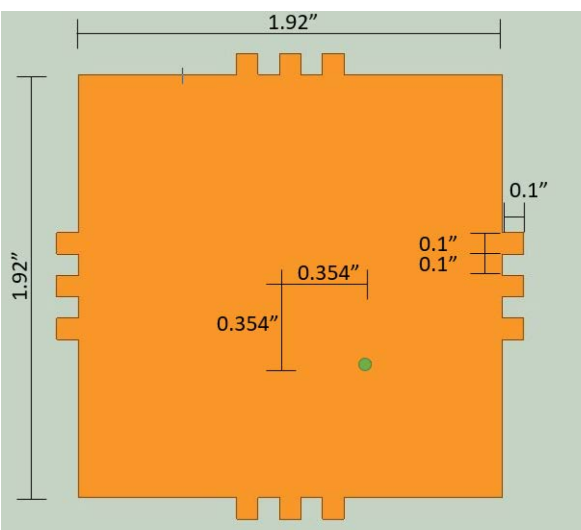

Figure 1: Desired Dimensions of Patch Antenna after Simulations in HFSS.

A 3D printing company with the capability to print in conductive materials was contracted to manufacture the antenna. The team designed a testing fixture to mount the patch antenna into the engineering test range at Ball Aerospace’s facility. After testing, the engineering range data is compared to the expected data from HFSS to determine if the 3D printed antenna has similar properties to a conventionally manufactured antenna.

Evaluation and Pre-design of a Peracetic Acid Disinfection Challenge

41

Client(s): Jim McQuarrie and Edyta Stec-Uddin at MWRD
Faculty Advisor: Branden Gonzales
Technical/Social Context Consultants: Dr. Tzahi Cath, Dr. Kristin Mikkelson, John Bush, Sara Schwarz, Jeff Norris, Don Hansen, Tanya Bayha
Team Name: Oxidizing Innovation
Team Members: Macy Kiel, Jon Paz, Erin Kim, Parker Anderson, Levi Riley, and Michelle Schwartz

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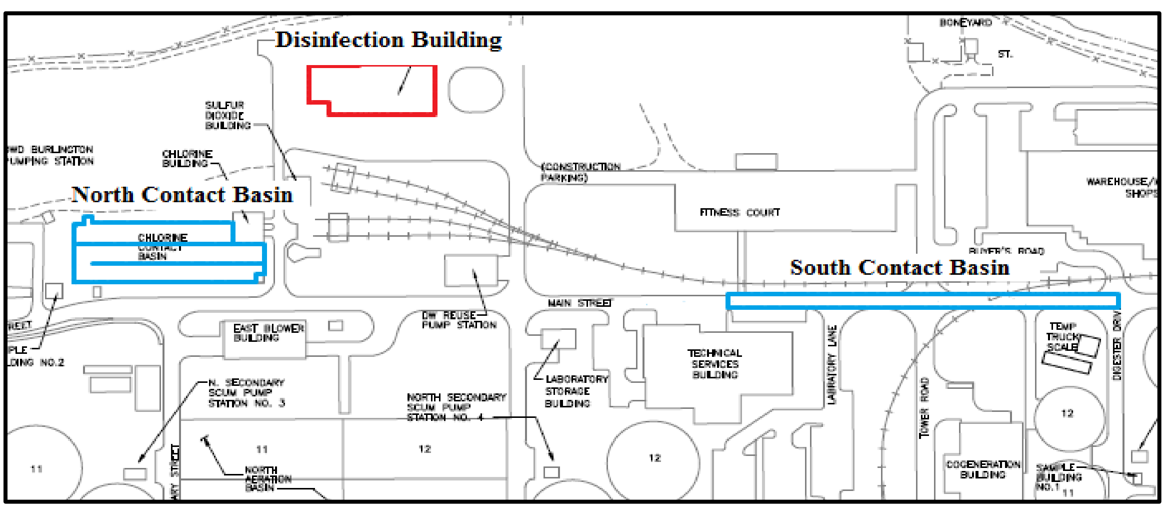
The Robert W. Hite Treatment Facility (RWHTF) in Denver, Colorado receives approximately 220 MGD of wastewater from the greater Denver community. As a part of the wastewater treatment process and to meet permit requirements, Metro Wastewater Reclamation District (MWRD) must disinfect the effluent water from their facility prior to releasing into the South Platte River. Currently, the disinfection process used at the RWHTF is chloramine disinfection, which is a conventional disinfection technique. As a part of this disinfection system, MWRD must dose the following chemicals into the contact basins in order to reach effluent permit levels: sodium hypochlorite, sodium bisulfite, and aqua ammonia. However, this system risks releasing harmful chemicals into the environment and currently involves complex chemical distribution systems and high chemical costs.

Oxidizing Innovation was tasked to consider peracetic acid (PAA) as an alternative disinfectant to the current chloramine disinfection system. Using PAA disinfection would reduce the number of chemicals MWRD would have to purchase, allow for a simplified chemical distribution system, and prevent the formation of hazardous chemicals in the outgoing stream. In order to determine whether PAA is a feasible disinfectant for the RWHTF, Oxidizing Innovation was asked to perform a tracer test on the existing contact basins, seen in the figure below, review financial analysis documents created by MWRD, simplify the chemical distribution system, and conduct a literature review about PAA disinfection in other facilities.



Current Locations of Disinfection Storage and Contact Basins at RWHTF

Hearing Aid Eye Glasses Challenge

42

Client(s): Dr. Brian Thomas
Faculty Advisor: Dr. Yitz Finch
Technical/Social Context Consultants: n/a
Team Name: Clairaudience
Team Members: Mohammed Almousa, Jessie Burckel, Emma Petton-Counelis, Jacob Roberts, Yilin Wei, Alanna Winfield

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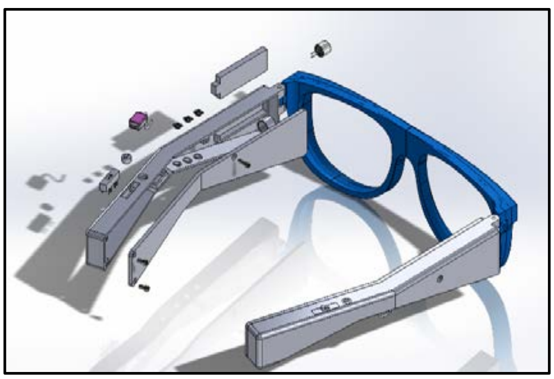
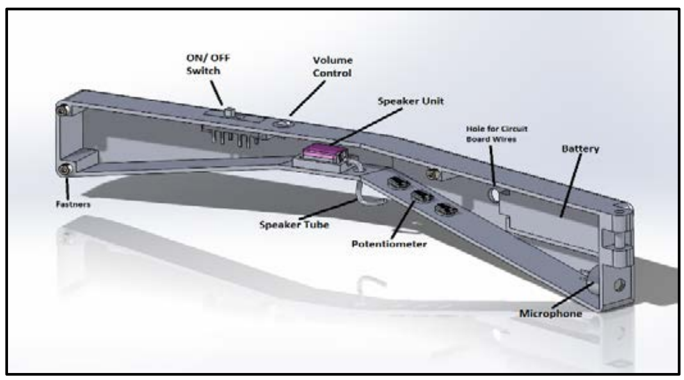
An investigation by John Hopkins Medicine in 2011 found nearly a fifth of Americans have hearing loss so severe that it makes communication difficult. The researchers found that overall, about 30 million Americans, or 12.7 percent of the population, had hearing loss in both ears. Hearing loss is often combined with vision impairment as age increases. Even though hearing aids greatly increase the ability for people to hear they come with a multitude of problems that make them difficult to use and inefficient at times. Part of this problem comes from the fact that the hearing aids are picking up all the noise available and are not able to filter it. Another problem is the location of the microphones and speakers, which introduces feedback into the electrical system and picks up a lot of background noise. Dr. Thomas from Colorado School of Mines has proposed a solution to this dilemma in the form of incorporating the hearing aids into the frame of glasses, so the microphones and speakers can be separated and provide directionality for users and a decrease in feedback.





The primary goal for this project is to design a functional prototype of hearing aids combined with a pair of eyeglass frames. The function of this design will be to improve the situation for users who have both visual and hearing deficiency by incorporating the hearing aid into the frame of the glasses. This will also aid with directional hearing because the microphones can be placed closer to the front of the face so much of the sound is being received from where the user is facing, giving less attention to background noise. Separating the microphone from the speaker will give enough space to reduce feedback through the electronics system. Our team is designing this model with the aim of effectively addressing common problems with modern hearing aids and providing a cheaper solution for users.

Food Computer Challenge

Client(s): Dr. Kevin Moore, CECS Dean
Faculty Advisor: Adam Duran
Technical/Social Context Consultants: N/A
Team Name: Team GreenWorks
Team Members: Duncan Flint, Matthew Twardy, Joshua Morand, Trevor Haanstad, Logan Schulke, Thomas Caracena, James Davenport

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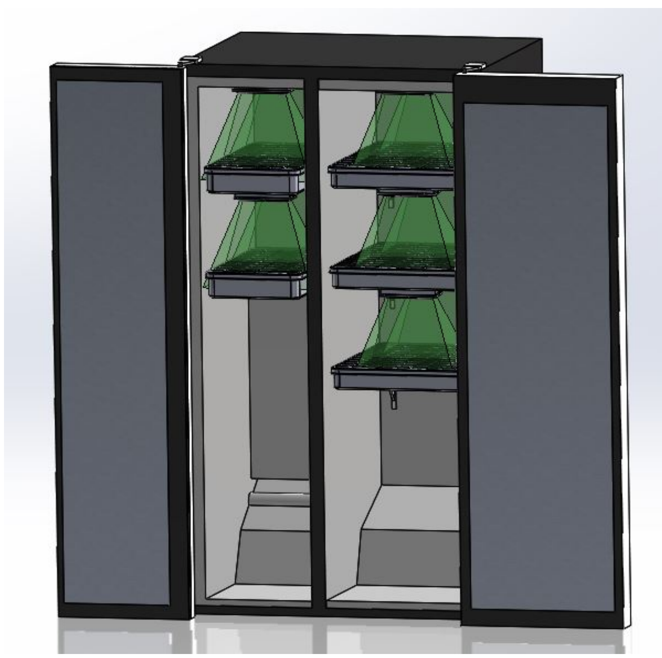
Today, over 37% of the Earth's arable land is being used for agriculture, which is equivalent to about 60 times the land currently occupied by the World's cities and suburbs. Even with all this landmass allocated for food production, people in all countries, both impoverished and first world still lack access to essential nutritionally robust food sources. For example, in the United States alone, about 23 million people (7% of the population) live in what are known as food deserts, areas lacking access to wholesome foods such as fresh fruits and vegetables. In an effort to address this ongoing global problem, Team GreenWorks has developed a custom ood computer aimed at growing enough fresh vegetables for a family of four while requiring minimal user interaction.



Food Computer Features:

- Custom LED "Light Recipes" featuring Wavelength Control
- Climate Control
- Nutrient Monitoring
- Automated Hydroponic Duty Cycle
- Simple, Remote User Interface

This project focuses on the automation and customization of food production with the ultimate goal of providing a sustainable source of leafy greens to those that may otherwise not have access. By taking advantage of photobiology and proven hydroponic techniques alongside implementing an automated nutrient delivery system, environmental control and a customizable user interface, the team believes they have found a unique solution that tackles the problem in an innovative fashion.

Sand Wash Basin Freshwater Neutral Development of Natural Gas Resources

44

Client(s):	Rowlan Greaves, Strategic Solutions, Southwestern Energy
Faculty Advisor:	Adrianne Kroepsch
Team Name:	FresH_2O
Team Members:	Stephanie Panza, Hayley Armstrong, Paige Becker, Mark Doolin, Olivia Cain, Kristina Johnson

Northwestern Colorado is rich in energy resources but constrained in water resources, which makes it an excellent location for innovation in freshwater-neutral oil and gas development. In this project, Team Fres$H_2$0 extends Southwestern Energy's industry-leading water conservation initiative (ECH_2O) by applying its principles to the Sand Wash Basin and the Yampa River watershed (Figure 1). Given theoretical data for the field, the team designed an oil and gas development scenario for a specific area of interest in the basin, and determined that 207 million barrels of freshwater would be needed for drilling and hydraulic fracturing over 25.5 years. The team then designed a plan to meet those water needs while maintaining a net-zero hydrologic impact on local freshwater resources. The plan maximizes alternative water use/reuse and incorporates conservation projects to offset any remaining freshwater demands (Figure 2)

Figure 1: FresH2O, Sand Wash Basin

The team based their design choices on insights gained from in-person interviews with water stakeholders in Craig and Steamboat. FresH_2O's plan pursues alternative water sources such as flowback water, coalbed methane produced water, and coalmine discharge water. Recommended freshwater offset projects include supplementing flows in the Yampa River to favor native fish species and employing Northern Tamarisk beetles to reduce water-consuming invasive Tamarisk plants, among additional options.

Figure 2: Southwestern Energy's ECH2O (Energy Conserving Water) framework (SWN, 2016)

Gabion Band Ring Beam Challenge

Client(s): Seth Wachtel, Randolph Langenbach
Faculty Advisor: Rebecca Dimond
Technical/Social Context Consultants: Dr. Joseph Crocker, Dr. Robert Amaro, Dr. Greg Rulifson, Dr. Shiling Pei
Team Name: Banding Together
Team Members: Caitlin Kaltenbaugh, Jessie Berndsen, Jared Roberts, David Pum, Molly Epstein

In April of 2015, an earthquake of magnitude 7.8 hit Nepal and devastated many areas in the Kathmandu region through tremors, landslides and avalanches. Many people lost their homes and in the aftermath of the disaster many were left wondering how to prevent this from happening again in the future. About 60 percent of Nepal’s buildings are simple, unreinforced masonry structures and are in remote mountainous regions (making it difficult to bring in materials that could improve the reinforcement of these homes). The local people of Nepal needed a solution that used locally sourced materials and that would be straightforward to implement. This is where Randolph Langenbach stepped in with his solution: The Gabion Band.

The Gabion Band uses ring beams of stones wrapped in strong wire mesh to tie masonry walls together and to help create more stability in seismic events. This idea applies the concept of gabion baskets, which are used in retaining walls, to homes. The Nepalese government wants strong evidence that this solution will be effective before letting it be implemented and added to the Nepal National Building Code (NBC). The goal of the Colorado School of Mines (CSM) Senior Design team is to test and find evidence to either support or reject this concept.

The Gabion Band Ring Beam Challenge is a joint venture between the CSM Senior Design team, Banding Together, and architecture students from the University of San Francisco (USF). The team from USF, led by Seth Wachtel and working closely with Langenbach, created various proposed designs of masonry homes that included Gabions. The CSM Senior Design team then checked the designs with the NBC and evaluated their resistance to seismic activity through hand calculations, finite element analysis (FEA), and physical models. The teams worked together in an iterative process. The CSM team sent their critiques to the USF team, who would then refine their models and the iterative cycle would repeat. The Equivalent Lateral Force (ELF) method was used to find a static force that would represent an earthquake of appropriate magnitude for the region. SolidWORKS, a FEA program, was then used, along with the results of the ELF method, to compare models with and without Gabions to one another. The physical testing took place with small scale homes, with and without Gabion layers, on the Mines shake table to further prove the legitimacy of the Gabion Band.

Children's Prosthetic Arm

46a

Client(s): Assortment of Children and Boa Technologies
Faculty Advisor: Dr. Joel Bach
Technical/Social Context Consultants: Dr. Jared Dean
Team Leads: Madison Millard, Clinton Parapat
Team Members: Adam Young, Rob Waite, Cari Smith, Kacey Bennett, Molly Clark, Brittany Marshall

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The team is to design a durable, low-cost prosthetic arm. The intention is for this design to be acceptable for *any* child with a transradial amputation(s) caused congenitally, by trauma, or by disease, and as such should not limit users by cost or size. To keep the costs down, we integrating Boa Technology into a design consisting of low cost materials. To allow for various size children to have access, we plan on making use of the high adjustability that Boa Technology offers. The Boa cables also allow for adjusting to compensate for child growth so that the prosthetic can be used for longer. The arm is to allow the user to have capabilities including: riding a bicycle, swimming, and going horseback riding.

There are three main subsystems that the design encompasses: the adjustable arm sleeve system, the mounting and rod system, and the hand. The inner sleeve is composed of neoprene and a poly-cotton blend. The outer sleeve is made of thermoformable plastics, neoprene, and support synthetic material, along with the incorporation of Boa reels. The mounting and rod system consist of aluminum, HDPE (high density polyethylene), and corrosion resistant springs. The hand consists of 3D-printed plastic, HDPE, aluminum, and Boa Technology. The design of the systems allows for the arm to grow as the child grows. The systems are rigid enough for support, water resistant, and have the ease and capability of adjustment.

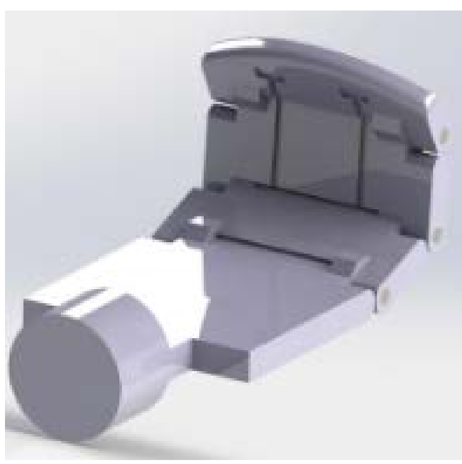


Image 1: Hand System Design

Prosthetic Crack Climbing Foot

46b

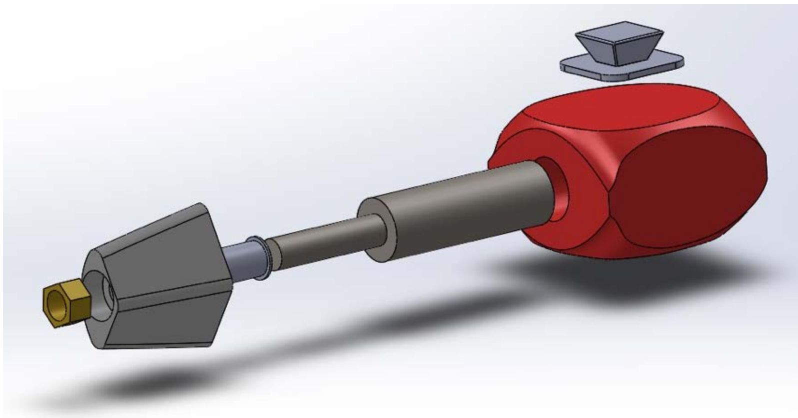
Client(s): Craig DeMartino, Adaptive Adventures
Faculty Advisor: Dr. Joel Bach and Prof. Jered Dean
Team Name: Human Centered Design Studio
Team Members: Adam Jensen (co-lead), Brittany Marshall (co-lead), HCDS members

Climbers who have transtibial amputations face all of the tasks of climbing without a functional ankle and foot. The Prosthetic Crack Climbing Foot (CCF) allows adaptive transtibial amputee crack climbers who wish to perform advanced crack climbing maneuvers the capability to do so.

With the current climbing foot on the market, the user encounters trouble with the foot becoming stuck in the crack when the crack approaches sizes ranging from one to two inches. Without inverting and everting capabilities due to the transtibial amputation, all available range of motion is from a coupled motion between the hip and the knee. When the hip and knee are aligned for standing, these ranges of motion are not accessible. As a result, disengaging the current foot once it is stuck entails removing a hand from the rock wall while pulling the foot from the crack. Additionally, using the foot as leverage involves a complex biomechanical movement (adduction and internal rotation). This widely used movement creates moments in the prosthetic socket that increases the risk for pressure sores and pain after climbing.

Combatting these problems requires creating a new degree of freedom. After considering many possible design paths, the team concluded that a design that rotates as compensation for the lacking ankle motion would be the best solution to this design challenge.

Designing a foot that is both strong and lightweight while not sacrificing stability when introducing rotating parts has proven challenging. These difficulties were overcome through collaborative planning about materials choices, shaft design, and creative placement of mechanical components. See Figure 1 below for the conceptual design of the CCF.

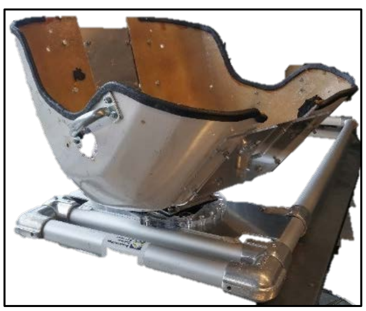


BOEC White-water Rafting Seat

46c

Client:	Jaime Benthin, Breckenridge Outdoor Education Center
Faculty Advisors:	Dr. Joel Bach & Dr. Jered Dean
Technical Consultant:	Dr. Robert Amaro
Team Name:	Raft Seat Design Team
Team Members:	Geordie Campbell, Briana Farris, Adam Jensen, Adam Peszek, Brittany Marshall, Cari Smith, Chad Brockman, Clinton Parapat, Hayden Rutherford, Maddie Millard, Rachel Keatley, William Bellis

The Human Centered Design Studio is a senior design group dedicated to enabling individuals, particularly those with disabilities, to try new activities and/or push their performance limits in the activities they are already involved in.



The raft seat design team created a white-water raft seat system that is both functional and affordable for disabled individuals who partake in the activities of the Breckenridge Outdoor Education Center (BOEC). This design provides support for hemiplegia of individuals ranging from children to small adults. The raft seat supports individuals up to 225lb while eliminating entrapment hazards caused by whitewater rafting. The raft seat allows the end user to be closer to the water than current equipment used, and can be adapted for both the right and left sides of the raft.

The raft seat design team utilized equipment that BOEC already has or can easily obtain to create a cost-effective system for white water rafting. The trailer frame is the main point of contact between the seat and the raft, and is to be secured to the raft using cam straps. The sit-ski bucket was altered to allow expansion for individuals of different sizes, and was fitted to a swivel to assist the rafting guides in safely helping individuals into the raft. Such items include a trailer frame, sit ski bucket, and swivel seat. Down River Equipment assisted the Raft Seat Design Team with supplies such as tubing, the swivel, and brackets. Down River also completed all the aluminum welding shown in the figures.

Adaptive Saddle

46d

Client(s): Nicole Robinson, National Sports Center for the Disabled
Faculty Advisor: Prof. Joel Bach and Prof. Jared Dean
Team Name: Human Centered Design Studio
Team Members: Edgar Crockett, Benjamin Harju

The National Sports Center for the Disabled (NSCD) offers therapeutic horseback riding for people with disabilities. Currently, there is a custom saddle with built in attachments allowing for a seat back to be utilized with the saddle. The NSCD tasked us with redesigning and building an improved back for a western saddle. They also tasked us with designing and building a universal attachment. The universal attachment needed to be able to attach to a variety of saddles and integrate with the redesigned backing. The combination of the redesigned back support and the universal attachment will allow for an easier and more broad use of the adaptive saddle.

The final product has a fixed low back support to provide stability and comfort. The fixed support also assists in shifting the weight of the rider forward to be over the front legs of the horse, which is important to keep the horse comfortable. There is an adjustable middle back pad which attaches to two lateral supports. This accommodates a wide variety of riders at various heights. The lateral supports go under the armpits to provide stability and support. The two lateral supports adjust horizontally as well as vertically to allow for adequate support; they also rotate down when the pin is out to allow for easier mount and dismount, especially in emergencies.

The universal attachment mechanism is a custom clamp that attaches to the cantle of the saddle and is tied down to the two rings on the cinch strap of the saddle with a strap. This strap helps stabilize the attachment. There are two vertical posts on the attachment to interface with the back. This provides the support and integration so the redesigned back can be used with any standard western saddle.

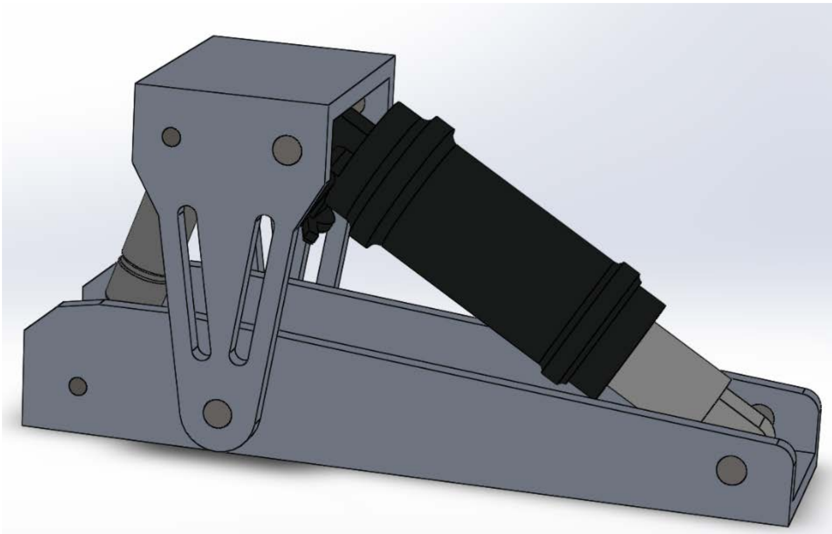
The redesigned back provides more comfort for the rider and the horse, increased safety, and support. With the prototype of the universal attachment riders can use the appropriate saddle but still have the support of the backing. Utilizing both together will offer a much better therapeutic experience and open the doors to more people being able to ride horses.

Snowboarding Prosthetic Foot/Ankle

46e

Client(s):	Amy Purdy
Faculty Advisor:	Joel Bach
Technical/Social Context Consultants:	Jered Dean
Team Name:	Human Centered Design Studio
Team Members:	Abby Zimmerman & Ryan Gyorkos

Our client, Amy Purdy, is a world-class snowboarder and Paralympic medalist. She is a bilateral, trans-tibial amputee and the co-founder of Adaptive Action Sports. The current prosthetic foot and ankle that Amy uses for snowboarding only allows her to lean forward (dorsiflex). Our project is centered on creating a prosthetic that also allows her to lean back (plantarflex). Having a prosthesis that allows both dorsiflexion and plantarflexion helps to better mimic the range of motion of a natural foot and ankle. Also, as a Paralympic snowboarder racing in multiple events, Amy Purdy wanted the ability to adjust her prosthetic in a timely matter. The level of adjustability that she grew accustomed to using her current prosthetic, the Versa Foot, needed to be applicable to our new design.



In order to best meet the project specifications, the prosthetic foot and ankle was comprised of a dual shock system under preload. Applying a preload to both shocks allowed for simple pin-hole connections instead of pin-slot connections. This was important, as snow and ice could easily build up in any open slot in the environment that the prosthetics would be used in. The shock that was chosen for the anterior of the prosthetic was a mountain bike shock, as these were the only models on the market that allowed for different rebound rates using a simple switch that is easily accessible. A model of our prosthetic foot can be seen in the image above.

Bi-Ski Impact Outrigger

46f

Client(s): Bobby Luscinski, Enabling Technologies
Faculty Advisor: Dr. Joel Bach
Technical/Social Context Consultants: Enabling Technologies
Team Name: Human Centered Design Studio
Team Members: Adam Fox and John Hefner

Enabling Technologies is an adaptive sports equipment developer based in Denver, Colorado that specializes in mono and bi-ski design and distribution. Bobby Luscinski, of Enabling Technologies, tasked our team, Human Centered Design Studio, with designing, building, and testing a new outrigger support system.

In redesigning the current outriggers that are made and distributed by Enabling Technologies, special considerations were taken in regarding the outrigger's performance on a groomed slope and on a mogul run. Previous models provided exceptional performance in one situation or the other but not both. Outriggers placed on the rear of the sit-ski handled moguls by could not carve as well as front mounted outriggers developed by competing companies. Rigid outriggers placed at the front of the sit-ski carved well on an open slope but presented a problem when encountering moguls and had a tendency to buck the rider forward over the point of impact.

Our more versatile outrigger design sought to eliminate the issues moguls present while enabling consistent turning. The outriggers are designed to be mounted at the front of the ski (near the rider's feet) for greater control when carving on the slopes (Figure 1). Our design also employs compression springs (Figure 2) mounted in-line with the action of impact with a mogul so the outriggers absorb some of the impact instead of bucking the rider out of the seat without compressing significantly in turns.

Figure 1: Full Outrigger

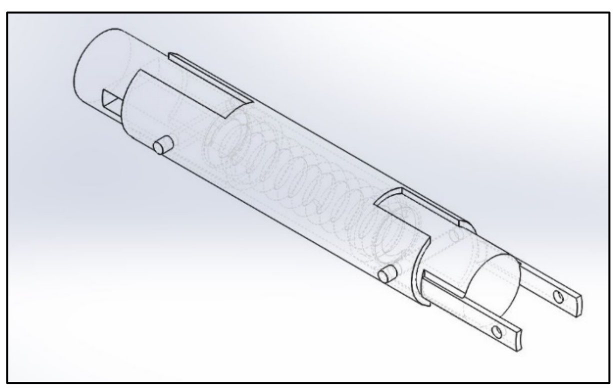


Figure 2: Compression Spring Housing

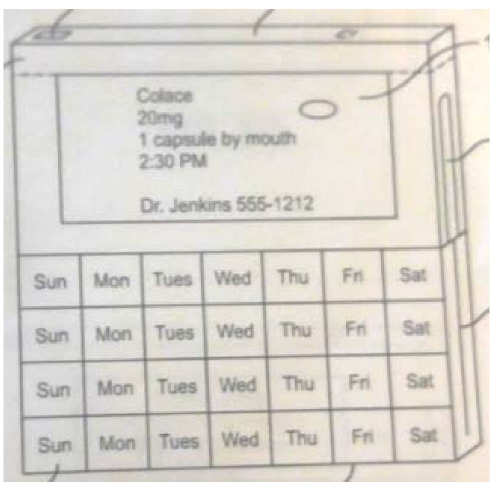
Smart Pill Box

46g

Client(s): Shannon Lapham
Faculty Advisor: Dr. Bach
Technical/Social Context Consultants: Jered Dean
Team Name: Human Centered Design Studio
Team Members: Craig Steinke, Vaughn Ericson, Marshall Trout, Adam Nadolsky, Briana Farris, David Delgado, Peter Mladinich

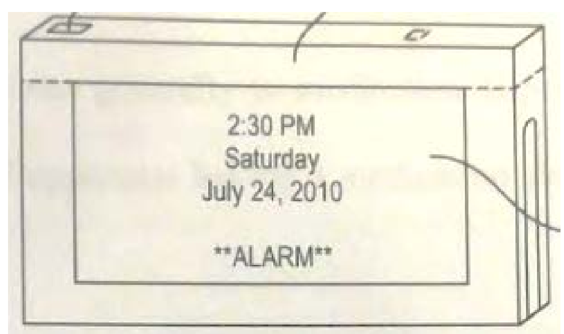
One of the Projects worked on by the Human Centered Design Studio is the Smart Pill Box. We worked with a patent owned by the client, Shannon Lapham, and created a working prototype she can use as a proof of concept for companies looking to license her product.

The Smart Pill Box we designed is similar to the concept picture to the left. The box consists of two major components. The top of the box contains a touchscreen that allows you to access the patient's medical history and view the patient's pill taking schedule. The medical history is available so that if there is an emergency, first responders will have a better understanding of what the patient is taking and can be alerted of potential allergies to medications and preexisting conditions. The screen will also display a reminder when it is time for the patient to take medication.



The box that the screen is on houses the pills for storage. When it is time for the patient to take the medication, they will slide the pill box out on a set of rails and take the medication for that day. The screen will display images of the pills that the patient should take, serving as a visual affirmation that they are taking the correct medication.

The idea behind the Smart Pill box is to have a device that can help remind people when to take their pills. This will prevent people from forgetting to take medication, or accidentally taking incorrect medications.



Transfemoral Prosthesis Joint

46h

Client(s):	Zach Harvey, Creative Technology
Faculty Advisor:	Dr. Joel Bach, Mr. Jered Dean
Technical/Social Context Consultants:	Medical Technology
Team Name:	Human Centered Design Studio
Team Members:	David Delgado, Peter Mladanich

Transfemoral prostheses (figure 1) are used when persons undergo above knee amputations. The prosthesis is a mechanical replacement for a biological leg that can integrate with the person's residual limb to compensate leg movement.

The issue presented by our client, Zach Harvey, was that persons with above knee (AK) amputations sometimes have a condition known as contracture (see figure 2). Contracture, within the context of this project, is when the residual hamstring muscle has difficulty contracting and flexing. This difficulty prevents persons with AK amputations from fully extending their residual thigh. This poses obvious problems associated with gait and posture.

Figure 1: Transfemoral Prosthesis

The current method used by Creative Technology to mitigate this problem has been to add plaster and other material to the socket to correct for the misalignment. Although this is a valid solution, it is only temporary as the contracture may decrease during physical therapy. Our design studio has designed and tested a transfemoral prosthesis joint that would be implemented in lieu of the rotator seen in figure 1. The joint can be seen below in figure 3. The joint would allow for the adjustment of leg angle based on individual client's level of contracture. The joint would be adjusted as the client's contracture improves, eliminating the need for adding plaster to the existing socket, or replacing it entirely.

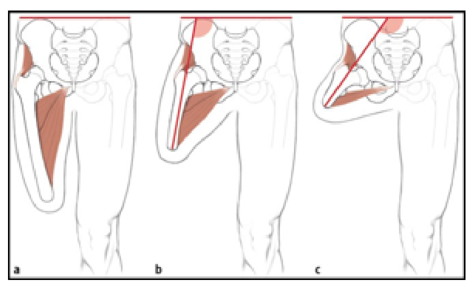


Figure 2: Contracture on an Above Knee Amputee

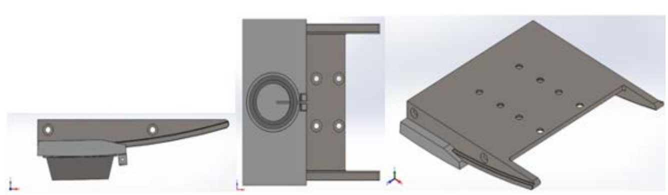


Figure 3: Transfemoral Prosthesis Joint

Hydro Turbine Governor Test Stand Challenge

47

Client(s):	Veronica Ferro and James Volk, Segrity LLC
Faculty Advisor:	Prof. Maria Carolina Payares-Asprino
Technical/Social Context Consultants:	Prof. Buddy Haun
Team Name:	Team Hydro
Team Members:	Nick Taylor, Kevon Hayes, Jeffrey Stephens

Basics: Develop a digital control test stand which can be used for in-house validation testing of a new governor system and be installed on an existing governor system in the field to allow testing of the unit governor system while the unit is operating.

How does it work?

Conventional hydro turbines bring water into a turbine through "Wicket Gates" or a "Needle" depending on the turbine type. This water hits turbine blades, spinning a large generator shaft. This shaft is connected to the rotor of a generator which is used to generate 3-phase power. Traditionally, the speed of a hydro turbine generator was governed by mechanical methods utilizing mass and damper systems. These older systems are being replaced by digital control systems using feedback loops, hydraulic actuators, and other electronic sensors. The conversion to these new control systems have unfortunately been plagued by premature failure of the hydraulic actuators years before their expected lifespan.

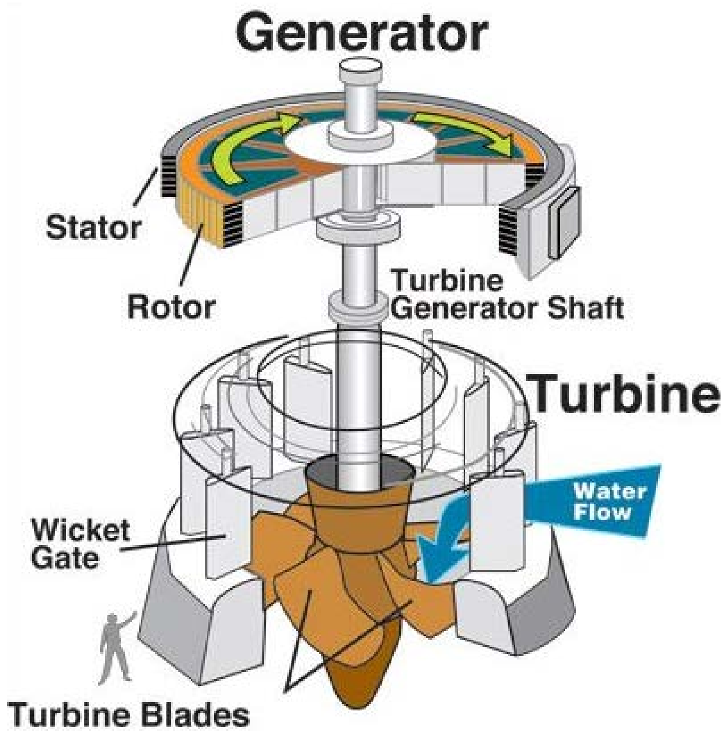


Photo Reference: http://www.myhydropower.com/2016/04/how-hydropower-power-plant-works.html

Our Solution:

Team Hydro has developed a test stand using the National Instruments Compact Reconfigurable Input Output (cRIO) device. Our client will use this test stand to perform a detailed analysis of the time and frequency domains of the control system. The test stands captures multiple signals and reproduces these signals to input different disturbances to the system. Therefore, it produces standard feedback analysis tools such as Bode plots, step response graphs, and fast fourier transforms (FFTs) for our client to study. Our test stand shall finally shed some light on many of the system failures being experienced in the field.

Individual Broader Impacts Essay

This semester all Senior Design students were assigned to write and submit an individual essay about how their engineering choices impact the social, environmental, and/or economic lives of communities and individuals. The topic for this semester's essay is:

Designed systems can impact the behaviors of people and environments. Present a discussion, using a contemporary, concrete example, of how an engineered system has positively or negatively impacted the behavior of society, the environment, and/or the economy. The essay should be either related to your project or your field of engineering.

The top 10 essays from this group of 314 senior engineering students were chosen by the course faculty and are included in this packet for your review.

Essay Title	**Author**
The Community Worth of Oil & Gas Development	Hayley Armstrong
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The top three essays have been judged by a panel of volunteer judges and winners of the best essay contest will be announced along with the Trade Fair results. This year's judges were:

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We thank you very much for your time and effort involved in choosing the top essays!

The Community Worth of Oil & Gas Development

Hayley Armstrong

The use of oil and gas in the United States is an extremely commonplace element of daily life in present society. It's so standard, in fact, that many times we don't think about where those resources came from, or the amount of work and money involved in their extraction. Despite the typical use and acceptance of these products, we often hear about the controversy and negative connotations surrounding the oil and gas industry. The type of media exposure the industry receives is almost never positive, and focuses on large and infrequent disasters, such as the BP oil spill in the Gulf of Mexico. The Dakota Access Pipeline is another example of a controversial project from the oil and gas industry that has recently taken over the media. When analyzing projects such as these, it is important to not only consider environmental impacts, but societal and economic effects as well. The pressure is high for oil and gas companies to be more concerned with the well being of communities, and emphasize corporate social responsibility as a whole. The industry must look to past developments for guidance and motivation to constantly improve operations. The Pinedale Anticline natural gas development in the early 2000's shows how a small community in Wyoming was both positively and negatively impacted by the oil and gas industry in a social, environmental, and economical context.

The town of Pinedale, Wyoming draws close parallels to the town in which my team's project is focused: Craig, Colorado. Therefore, it is very important to look at the history of Pinedale in order to predict what may happen in the future for oil and gas development in other small towns, such as Craig. When the industry began oil and gas exploration near Pinedale, many social changes were due for the community. Pinedale was about to become a classic example of a boomtown, a term associated with many mining communities. The population of Sublette County, in which Pinedale is located, increased by 68% from 2000 to 2013, six times the normal population growth rate for the nation [3]. Specifically, Pinedale saw a 30% increase in population from 2000 to 2006, a rate higher than any other towns in the county [6]. This population growth was not natural, but instead correlated with the increase in the rate of oil and gas drilling occurring in the Pinedale Anticline. When the population went through this rapid growth period, many other factors, such as the quality of living and access to public services, were expected to change too. One negative impact of the population boom was the increased cost of living in Pinedale. The population increase strained the housing industry's ability to produce enough homes to meet demand, therefore resulting in less availability and higher home prices [6]. This may not have been an issue for new oil and gas employees with high wages, but it was definitely a problem for current residents with lower wages who couldn't keep up with the cost of living [6]. The long-time residents and community of Pinedale were struggling as a result of oil and gas exploration near their town. Another negative social impact of the natural gas boom was a strain on public services and infrastructure, such as hospitals, public education, and law enforcement. The crime rates in the county rose significantly with the population increase and the number of arrests almost quadrupled from 2000 to 2006 [1]. An increasing number of trucks and traffic on the roads was due directly to natural gas development. Noise, accidents, and long-term damage to the roads were all undesirable consequences of the oil and gas industries moving in [6]. Sublette County as a whole was faced with the pressure of maintaining the quality of life so that new residents would hopefully become permanent residents.

According to socioeconomic analyst Jeffrey Jacquet, "…housing shortages and cost of living pressures currently insure that nearly none but the highest paid workers will permanently relocate to fill the vital jobs needed for a stable economy [1]." One of the short-term positive impacts of the natural gas boom was that millions of tax dollars were collected, which were used for infrastructure improvement and community resources [4]. Another short-term economic positive was that thousands of jobs were suddenly created for local residents, leading to a higher average wage for the county [6]. But when looking at Jacquet's point of view, mainly highly paid industry workers received these positive benefits, while other residents had to struggle to remain in Pinedale with an increased cost of living. One of the more prominent issues with oil and gas development in small towns is the history of a boom and bust pattern. The town "booms" when opportunities are discovered and the industry moves in, and "busts" when production is completed and the industry leaves. This concept can leave small towns in a state of economic devastation, essentially taking away the jobs and income of many workers who are not willing to relocate. Pinedale has not yet reached the "bust" phase, but who's to say what will happen when the maximum amount of resources has been extracted and the area is no longer economically valuable. Once that happens, many long time residents of the town may be inclined to say that having short-term economic benefits was not worth the complete social transformation of life in Pinedale.

Along with many social and economic changes, Pinedale also experienced some environmental changes. The environment surrounding the drilling of the Pinedale Anticline was impacted in slightly negative ways, but it is important to consider the efforts of the oil and gas industry to make technological advances during this time to in turn limit these impacts. In Sublette County, increased air pollution became a negative impact of development in the Pinedale Anticline field. Ozone alerts were more prevalent in the area starting in 2008, triggering symptoms for residents with weak immune systems or respiratory ailments [4]. “We recognize that definitely the main contributor to the emissions that are out there is the oil and gas industry…” said Keith Guille, a spokesman for the Wyoming Department of Environmental Equality [5]. The problems with the ozone levels represents a negative environmental impact that was associated with drilling, but the operators made positive changes in response to the pollution issue. The ozone was practically out of compliance with federal health standards when more stringent regulations were put in place by the state and the industry, such as performing completions without flaring and eliminating non-essential operations on high ozone days [2]. Other concerns developed over the industry’s impact on wildlife in the area. The mule deer population, for example, declined 60% from 2001 to 2009, and disturbances from energy development were to blame [4]. Well pad and road construction were the main factors contributing to habitat loss for the deer, as well as other local wildlife such as the sage grouse, pygmy rabbits, and pronghorn antelope [4]. Although Sublette County saw negative environmental impacts for surrounding wildlife, the oil and gas industry made a positive change to prevent more of these issues. For example, companies began clustering their wells onto a single pad and then using directional drilling, meaning fewer pads and road construction, resulting in less habitat disturbance [4]. When environmental issues pop up, it seems as if the oil and gas industry takes on more responsibility for their actions, making sure to lessen any impacts as soon as possible.

The natural gas boom in Pinedale, Wyoming quickly drew the interest of the oil and gas industry, and soon the town and surrounding county had changed socially, economically, and environmentally. When looking at the history of the town and how it changed in each sector, it’s apparent that the industry took on more responsibility for environmental impacts than socioeconomic ones. It also became clear that the town received the most benefits economically, and suffered some drawbacks socially and environmentally. Many times the economic benefits of oil and gas development do not outweigh the importance of quality of life for the current residents of a boomtown. When deciding whether or not to pursue oil and gas development in a small town, I believe it is of utter importance to consider what social changes the industry will bring. Oil and gas companies today focus greatly on environment impacts, and that is admirable, but they need to work on truly making a difference in communities. Hopefully companies will begin to recognize this, and leave communities in a better state of living than when they initially started production.

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Give Me a Brake: Autonomous Braking and Driver Attentiveness

Adam Cameron

It was May 7, 2016. In Williston, Florida the temperature was 66 degrees—the perfect weather to go see a movie. The movie was Harry Potter, but it was not showing in theaters, and neither was Joshua Brown sitting on his couch. Mr. Brown did watch Harry Potter that day, but he did so from the front seat of his Tesla Model S, which was equipped with an autonomous driving system. Mr. Brown had used this feature of his Tesla many times before, but on this day the bright Florida sun concealed the large, white semi that cut across the highway in front of his Model S. Joshua Brown died because his car slammed full speed into a semi-trailer, without ever realizing that it was there [1] [2].The cause of the crash was not a technological breakdown, nor was it the violation of any traffic law; instead, the crash was caused by Joshua Brown's misunderstanding of the technology he was using. Autonomous Emergency Braking (AEB) systems are used to help drivers avoid front end collisions, and they are an important part of any autonomous vehicle. AEB systems are not only used in fully autonomous cars; many modern passenger cars have AEB systems to assist with regular driving. These systems are meant to keep people safe, but they can also give people a false sense of security. While AEB system technology is a major engineering development in the safety of cars, it leads to a culture of carelessness, and until people learn to use it properly, it can actually be a danger to drivers.

One early autonomous braking system was introduced by Mercedes in 2005. The 2005 S-Class was able to detect problems, alert the driver, and prime the brakes for a faster driver response [3]. This early system aided drivers in braking more effectively, but it did not replace the need for the driver to depress the brake pedal. This system pioneered AEB systems without fundamentally changing the way drivers stopped their cars. Today, AEB systems are changing the braking experience. Every new Tesla vehicle comes with full self-driving hardware, including an AEB system [4]. Tesla no longer expects drivers to have to make emergency braking maneuvers. Whether this is beneficial or not, it is a huge departure from the societal norm that *people* drive, and stop, their cars.

There have been many studies that show how AEB systems reduce the rate of front end car crashes. The Insurance Institute for Highway Safety (IIHS) did a study in 2013 that showed that AEB systems reduced forward crashes by 23 percent. This study was done with real drivers driving real cars, some of which had AEB systems and some of which did not [5]. The results of this study are extremely significant, and it is studies like this that have led auto manufacturers to start making AEB systems standard. By 2022, 20 major car manufacturers, accounting for nearly 99% of all vehicles in the U.S., have agreed to make AEB systems a standard feature on all of their vehicles [6]. Like the invention of seatbelts and airbags, AEB systems appear to be an undeniable advancement in the safety of passenger cars.

AEB systems have been proven to be very safe, but what about the drivers who use them? Drivers such as Joshua Brown put too much faith in the ability of the AEB systems in their cars because they do not understand the true purpose of the system. Like a seatbelt or an airbag, an AEB system is only meant to help mitigate personal injury and lessen the extent of any injury that may occur. The difference between AEB and seatbelts or airbags is that AEB systems are proactive systems that are capable of deploying before a crash. In many cases, AEB systems are only meant to start the braking process earlier (like the 2005 S-Class), and they still intend for drivers to apply the brake with their feet. People are so used to what happens when *they* apply the brake that they assume an AEB will function in the same way. This misconception is the main societal impact of AEB systems. Autonomous systems are causing people to tune out of their surroundings and ignore many built-in survival mechanisms. When automotive manufactures decide to put AEB systems in vehicles, they inadvertently are telling people to put their instincts on hold.

AEB systems can be extremely useful, but they must be implemented properly. It must be clear to drivers that they need to be ready to brake, even when the AEB system is in operation. Perhaps more importantly, drivers need to know that once they take control from the AEB, they have full responsibility over the braking of the car [7]. This means that drivers must continue to practice slamming on the brakes during emergencies because even an accidental tap on the pedal will disable the AEB system. In order to be socially responsible, automotive manufacturers that put AEB systems in vehicles should promote the proper way to use their systems. There is a precedent for campaigns such as this—the slogan "click it or ticket" is a famous example for a similar campaign about seatbelts. This simple message reminds people that seatbelts only do good when used properly ("clicked" into place). The same could be done for an AEB. Another approach (which is not new) is to warn drivers of an upcoming obstacle and give them time to brake. Only if the driver does not respond should the brake be applied autonomously. In all cases, care must be taken by the engineers, manufacturers, and retailers of cars with AEB systems to ensure that the system is not changing how people react to emergency braking scenarios.

While the benefits of Autonomous Emergency Braking systems are numerous, the culture of inattentiveness that they promote can have negative impacts on how the average driver responds to emergencies. This is not to say that AEB systems should not be implemented. These systems save lives, and that is a societal impact that cannot be ignored. Like the airbag and seatbelt before it, AEB systems are sure to become a part of everyday life. The problem occurs in the transition phase; as AEB systems become more popular, drivers must familiarize themselves with the limitations of these systems. Since the technology is relatively new, it can be expected that people might not understand how these systems are designed to operate. It is the responsibility of automotive manufacturers to promote a culture of safe use of AEB systems. If manufacturers do not do this, they are allowing for a paradigm shift in how drivers respond to emergency situations, and this could be catastrophic.

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Returning Power to the Plow: How Mechanized Agriculture Hurts Farmers

Joshua Cunningham

The introduction of machinery to modern farming techniques offered efficient and profitable methods to producing foods for massive amounts of people. However, the nature of these advances marginalized many farmers from their jobs and livelihoods. Mechanized farming is a prime example of how technological advancement is meant to improve the well-being of humanity, but has unforeseen consequences on those who would use its alternative.

Farming and agriculture are some of the first fields in which technology has increased productivity to better human living standards. The reason that human population has grown so drastically over the last few centuries is out ability to grow food on a large scale, and by a relatively small proportion of the population. However, when these advances exclude people that previously made their living in this area, it shows how technology makes negative societal impacts unforeseen to its creators. Mechanized farming equipment was first introduced in the United States in the early 20th Century [1], and radically changed the volume of product a single farming unit could produce. Before this point, farms would be run by dozens or hundreds of workers depending on the size of the property, and communities would be built around these systems. When machines were introduced that could do the work of all of these people put together, there was suddenly no need for these rural farming communities anymore. Many families were displaced and to this day the amount of labor that would take a small town to produce by hand can be done by one family and a few machines. Engineers developed this technology to make farming more efficient but in the end created something that had a huge negative impact on many people's lives.

An example of this impact is seen in the country of Burkina Faso in central Africa. This nation has had many troubles stemming from colonialism, leading to movements trying to break down the elitist norms that kept land owning exclusive to the rich members of society. Eventually laws were created that prevented private ownership of land. All property was owned by the government, but could be claimed by "those who could work it" [2]. So the norm of the area was that small communities or families would work the areas that they could with the limited resources they had. The land could be seen as a collection of many, small farmlands. Then, in the late 20th century, when outdated tractors from Europe made their way into the country, the social and economic climate changed. Those who could afford to own these tractors would use them to plow their land. However, for these machines to be used efficiently, they need to be used over areas much larger than the typical plots common to the farmers at that time. Subsequently, the rich farmers would buy up the land around them, displacing those people, so that they could make the most of their investment. Additionally, the tractors require training to use, meaning not all workers were eligible to use them. This led to the land consisting of fewer, larger farmlands. One additional effect that tractors had on the society was that women were worked harder as a result of the tractors replacing the men's jobs. Traditionally, men would plow the fields while the women weeded and harvested behind [2]. With the plowing being done by tractors, the women were expected to keep up to unreasonable speeds. Marginalizing the poor and putting them out of their livelihoods is a common theme in many cases where mechanized work is introduced. Even the United States was not immune to these effects when the technology was first developed. More advanced machines than the ones seen in Burkina Faso could pick the produce right off the plants, as well as spread the seeds for new ones. These machines made hand labor completely obsolete, and removed the livelihoods of many people. These impacts could have been mitigated if the communities or the governments of the time had foresight into the issue and had placed safeguards against a rapid upheaval in social norms. The government of Burkina Faso is now trying to implement reforms to make small machinery more affordable for small scale farmers so that the agriculture is not so biased towards the already affluent.

The social impacts of mechanized agriculture are not all bad, though. It is only through these advances that we are able to support such large populations of people, especially in such dense cities in modern times. It is responsible for the increase in health and availability of food for most of the world, and in many areas of industry, people look for ways to do jobs that are strenuous to human workers, so why should farming be any different? All this is to show that an argument can be made that the good that these advances made in productivity outweigh the negative impacts. While that may be true, the important lesson to learn is that all progress comes with unforeseen consequences. Engineers and designers should be expected to try and mitigate these effects, but it would be impossible to anticipate the large scale changes an invention would have on the world. Society changes with the times, and it adapts to how people shape it. Engineers should try their best to bring health and happiness to people, while ensuring that these benefits to some do not detract from the benefits of others.

Mechanized farming is one small example of how an improvement to one facet of society can have negative impacts on the rest. Sometimes it is only after the changes happen that people can assess the broader impacts a technology can have on people. For the people in Burkina Faso and the United States, that impact was community upheaval and a shift from the large scale rural control of agriculture to the small scale large volume production of mechanical agriculture. Because these effects were not intended, they serve as a warning to those who would try to change humanity for the better by radically changing societal norms.

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Beyond Human Capabilities

Rebecca Fallon

Growing up and throughout life, people indulge in recreational activities that bring them joy and experiences, which in turn, enable them to live their life to the fullest. While this ability is often taken for granted by able-bodied people, there are many individuals in today's society with physical handicaps that preclude them from having these experiences. Engineering has taken steps to fulfill an aspect of social justice by giving the physically disabled access to recreational activities that they wouldn't otherwise have. The development of prostheses has changed the lives of many who were once overlooked, however, the moral question arises: what happens when technology surpasses human capabilities and how does society handle physical advantage?

"Play" is the ninth listed central human capability that everyone should have according to the *Harvard Human Rights Journal* who defined it as "being able to laugh, to play, (and) to enjoy recreational activities" [1]. There are many groups, today, that focus on developing adaptive sports equipment for the physically handicapped including the Colorado School of Mines Human Centered Design Studio. Projects including prosthetic hands that will enable child amputees to swim and ride bikes as well as prosthetic feet for climbing and snowboarding are opening doors for people all over the country. This field has the capability of improving the quality of life for so many individuals. Kids can have normal experiences and not feel left out on everyday activities while adults can do the things they once loved or even things they've never been able to do before in their lifetime.

Amy Purdy, a double leg amputee has done unthinkable things with the prosthetic limbs engineering has provided her. She has competed in the Paralympics for snowboarding and even participated in the popular TV show, "Dancing With the Stars". Her astounding performances shocked the country that didn't think her achievements, as someone with a physical disability, were possible. The human foot contains more than 100 muscles, tendons, and ligaments that create a complex system for support, balance and mobility [2] that, at age 19, Purdy learned to function without. While her feet allow her to compete with able-bodied people, some have raised the question of having certain advantages. The question was addressed in an interview with her instructor where he explained that the only advantage was the lack of pain in her feet after hours of practice [3]. While some may see this as an advantage, the disadvantages of balance and control are much higher. Purdy is not the only one who has faced these types of concerns, however.

Oscar Pistorius, or as some know him, the “Blade Runner”, competed in the 2012 Olympics and raised some controversy for doing so. Skeptics wondered if his bionic legs enabled him to run faster than a person with normal legs giving him an advantage on a highly competitive field. Many scientific studies were performed to compare the abilities of his prosthetic limbs and the limbs of other athletes. The studies (while controversial) found that the swing time of his limbs was actually lower due to the decreased weight of the prostheses but, arguably, couldn’t generate as much force as a biological leg. Another dispute arose over fatigue, and while most people’s lower legs are the first to tire in a race, he would not have that problem enabling him to run faster for longer. Others argued that because Pistorius gets his energy the same way as any other human, he should be allowed to compete and only when “motors or alternative power sources are introduced” should an athlete be put into a different race [4]. The line is blurred, however, because the mechanics of running are so different for everyone and not fully understood and therefore Pistorius was allowed to compete. As technology improves, more answers or issues may develop. Right now, prostheses are becoming more and more advanced to the point that one day they could be better than biological limbs. Where does competition cross the line of “fun”? If someone finds that competing is their way of playing and perusing happiness, how can it be justifiably taken away? These are issues that will soon have to be addressed by society and based on the case of Pistorius and even Purdy they are already starting to be confronted by the public.

Something that was once a great progressive justice has started to shift to social injustice in that able-bodied people are possibly becoming less advantaged. As of right now, there hasn’t been any conclusive evidence of a case where a prosthetic limb creates an advantage for someone but it would be foolish to say that progress of this level is not in the foreseeable future. Society will have to decide what is justified in limiting people who were once limited themselves. By not allowing them to compete, the cycle repeats itself and a huge purpose for prostheses is overlooked while basic human rights are stripped. In some cases, it seems fair to have a restriction on the type of technology that they are allowed to use, but how can that be made universal to all disabled athletes? Many of the limbs that Paralympians actually have are custom made for them specifically and hard to replicate. It’s even possible that one day people will strive to get amputations in order to become better at what they do. At that point, there would have to be some separation of biological Olympics and robotic Olympics. Then more social issues get involved with class systems and the people who can afford bionic legs rising above the poor in more areas of life.

Engineers have had a multitude of successes in bringing equality to society for the physically handicapped however, in their attempts, have brought about new issues. With endless opportunities for improvement, engineering of the future may go above and beyond human capabilities. By making biological limbs outdated and unfavorable, it’s hard to tell where society will draw the line. Too far in one direction and infringement on human rights becomes an issue, while too far in the other direction spills over into robotic Olympics. The ultimate solution will have to take into account every individual’s right to “play” and to uphold that right on an equal playing field.

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Power Shortage: Social Impacts of Electric Transportation

Karl Grueschow

Electric transportation is popular in today's media given the current push to move away from fossil fuels. The success of Tesla Motors has reignited a spark in peoples' attitudes toward electric transportation, and manufacturers like Chevrolet, Ford, and Nissan offer full electric variants of their own. Depending who you ask, many people seem to believe that electric cars are better than combustion powered cars, and that electric power is the solution to our transportation energy problems. There are significant issues posed by a mass migration to an electrically powered transportation sector that often go overlooked, however, and these are challenges that engineers must not only address as we move forward, but effectively communicate to the public as well.

The first issue is storage. Currently, the dominant form of electrical energy storage on earth is pumped hydroelectric, where water is pumped from a lower reservoir to a higher reservoir to increase the fluid's gravitational potential energy. This is done when instantaneous energy prices and demand are low. When additional energy is required, the water flows back downhill through a turbine to recover that potential energy, with round trip efficiencies often exceeding 80 percent. [1] According to Energy Storage Association, the U.S. can store about 2 percent of its generating capacity, where other places like Japan and Europe capable of 10 percent and 5 percent storage, respectively. While this type of storage works on a grid-level system, it is impossible to implement for individual power systems like vehicles. For those, we need batteries, and battery technology is still problematic in terms of overall storage capacity, charge times, and electrochemistry. Battery capacity is increasing at a promising rate, but those batteries use chemistries that can pose significant dangers to humans. Lithium batteries currently offer the highest energy density, but require physical and electrical protection to prevent thermal overload and venting. As engineers, the safety of those who use our designs is paramount, and as such, vehicles powered by these batteries must be made with sufficient protection to prevent puncture in the event of a crash, which often means increased mass.

High speed electric mass transportation may offer an alternative to an electric vehicle (EV). personal transportation sector. An infrastructure capable of providing long-distance electric-based transportation could be a stopgap between the needs of local and regional transport. High speed electric trains are already in use in places like Japan, but the power required to accelerate these machines to high speeds and maintain that speed against the force of drag is significant. Power can be calculated by:

$$Power = Force \times Velocity$$

At higher velocities, force used to continue accelerating is being multiplied by a large number. In open air, the force of drag increases with the square of velocity, which dictates that the force required simply to keep a vehicle moving at high speed becomes significant. Using air travel as an example, the thrust required to maintain a Boeing 737's cruising velocity of 511mph (750ft/s) at a cruising altitude of 33,000ft is about 4700lbf (estimated at 85% of max cruise thrust for 2 CFM56-3C engines [2]). Instantaneous power is therefore:

$$4700bf * 750\frac{ft}{s} = 2{,}775{,}000lbf * \frac{ft}{s} = 6409HP\ or\ 4781kW$$

In terms of energy, a 3-hour trip (neglecting takeoff and landing) costs about 14,300 kWh- roughly enough energy to power a typical American home for almost a year and a half [3]. Consider the number of flights per day throughout the U.S. and it becomes obvious that high speed transport, even with the most aerodynamic vehicles, costs huge amounts of energy. This presents multiple problems in terms of storage, machinery, and transmission.

Certainly, aerodynamic drag is a major obstacle to high speed electric travel, but companies like SpaceX and Hyperloop One are currently exploring the option of high speed travel through evacuated tubes operating at near vacuum pressures, negating most the aerodynamic drag penalty. This would also allow electric machines to embrace one of their advantages over combustion machines: energy recovery. Motors can be designed to run as generators, and generators can be designed to run as motors. If there is little drag to dissipate a vehicle's kinetic energy, not only do we spend very little energy to keep the vessel moving at high speeds, we can recover much of the energy spent accelerating during the deceleration phase. About 60 percent of our energy in the US is lost to inefficiency [4], so being able to recover kinetic energy on that scale would be a huge step forward toward reduction of that inefficiency. Currently, every kWh of energy in the combustion powered transportation sector is lost to heat or drag. When we slow an airplane during landing using the brakes, every kilojoule of kinetic energy is being turned into heat, wasted to the atmosphere. Despite these challenges, there is certainly some benefit in the ability to recover a portion of that energy.

What, then, does an electric transportation sector look like? In 2015, the transportation sector consumed 27.7 quadrillion BTUs (Quads)- about 28 percent of overall energy consumption- operating at an approximate efficiency of 21 percent. 92 percent of that energy came from petroleum [4]. Electric power generation, however, comes from multiple sources, as shown in figure 1, (right). Shifting the transportation sector to electric power would increase demand for electric generation by 72 percent. Current estimates place US electric generation reserve power capacity at only about 25 percent average [5], drastically short of coping with such a paradigm shift. If we allowed the shift to consume only 15 percent of our reserve capacity, we could move about 20 percent of the transportation sector to electric power before overwhelming our current infrastructure.

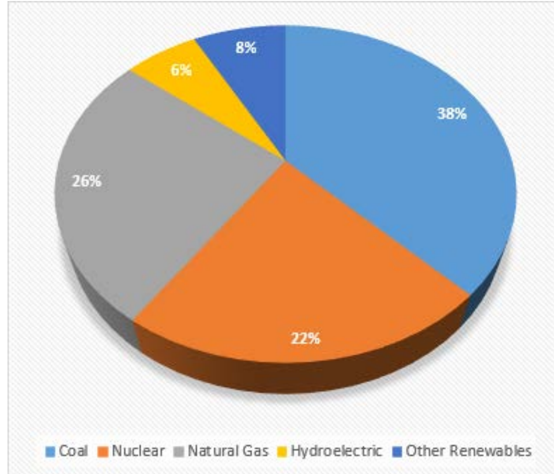

Figure 1: Composition of 2015 Electric Generation [4]

Another issue is that our aging electrical grid cannot handle a significant sector shift to electrical power. EV owners often point out that they charge their vehicles using solar panels installed on their homes and therefore don't impact the grid, but in terms of a major shift they become the exception, not the rule. Solar and wind represented 1.4 and 4.8 percent of electric power generation in 2015, respectively, and are not viable enough to supply our current demand, much less the increase in demand from a shifting transportation sector. The increased demand within the fossil fuel industries supplying electrical generation could very well drive up prices and essentially solidify both coal and natural gas as power generation resources for the foreseeable future, counter to the original intention to move away from them.

We must also acknowledge the issue of electric vehicle efficiency. Internal Combustion (IC) engines are often stigmatized as being ancient technology, dirty, and inefficient. They're certainly inefficient, but in terms of resource consumption, EVs are not appreciably better. Proponents cite electric motor efficiency in converting electrons into go-power, but they neglect the bigger picture. Inefficiencies multiply, and the EV narrative neglects inefficiencies on the generation and transmission sides. Rankine Cycle generation runs on the order of 30 percent efficient, and we lose an additional 6 percent in transmission. Electric motor efficiency is very good at peak power and torque, but we don't drive our cars at peak torque while maintaining steady speed operation. Motor efficiency decreases at lower loads, though not by much. Even if we assume 70 percent motor efficiency, 30 percent Rankine Cycle efficiency, and 96 percent transmission efficiency, our overall fuel conversion efficiency is only 20 percent from “coal” to “cruising,” not far removed from a typical IC engine. Even at 80 percent motor efficiency, our overall efficiency is only 23 percent. In terms of refined fuel resources, an EV consumes about the same as a dirty, ancient, combustion engine.

Electric transportation will play a significant role in our future. Clearly, there is room for both motive forces to complement one another while operating within the same sphere, but the notion that the transportation sector could move to pure electric is founded in technology and infrastructure that does not currently exist. The challenges facing mass electric transportation are significant, and much of the popularity of the concept appears to be based on a lack of public understanding of just how much energy we already consume in various sectors and the underlying processes that comprise electric power generation in the US. Better communication from engineers to inform the public would go a long way toward promoting constructive discussion on the subject. Perhaps if every American were aware of the magnitude of their consumption, they would not only be more conscientious in their energy consumption, but in their consumption of technology that uses that energy to its fullest. As engineers, we have a duty to fully understand the problem before we move forward with our designs, and that duty includes helping inform the public to make better policy decisions.

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Lights Out Manufacturing: Extinguishing Jobs

Adam Hall

Innovations in science and engineering impact and shape our society's economy, socio-economic structure, and environment. However, not all the effects of these innovations are seen in a positive light. For years, progress in the fields of science and engineering have been criticized by some artists and historians. Within both communities there exists a large group of people that believe in the paradox of development: Humans will inevitably cause their own demise from their progress in technology. This echoes in many pieces of classic literature such as Mary Shelley's *Frankenstein*. More recently, rather than being concerned about a mad scientist creating a monster from spare human parts, our society has a watchful eye on automation. As early as 1955, Phillip K. Dick's short story "Autofac" expresses this concern by questioning, "Man should want to stand on his own two feet… but how can he when his own machines cut the ground out from under him?" [1]. With competition mounting overseas, manufacturing with more automation has become most companies' goal. Some companies are taking this even a step further by creating "lights out" manufacturing plants that are so human independent that they can literally run with the lights out and with the air conditioning turned off. In Japan, a company called FANUC utilizes the "lights out" manufacturing model to manufacture industrial robots for other companies like Apple and Tesla so that they can come closer to "lights out" status [2]. These recent breakthroughs in manufacturing have sparked debate as to whether automation in manufacturing is beneficial for society. Automation in manufacturing positively impacts our society's economy and environment but, negatively affects our socio-economic structure.

Automation in manufacturing positively affects our society's economy. The use of industrial robots in the manufacturing process has been shown to increase productivity and increase overall economic growth. In 2015, Georg Graetz and Guy Michaels published a study using the industrial robot data from 17 different developed countries during 1993-2007 and found that as the density of industrial robot use increased, total productivity increased. In this case, the density of industrial robots is the ratio between the number of industrial robots and human workers. The same study also found that the increase of industrial robot use in 1993-2007 increased the annual GDP and productivity by 0.37 and 0.36 percent [3]. Some people may look that those numbers and say that 0.37% and 0.36% are small, but those growth percentages are on par with the growth associated with steam technology in Britain during 1850-1910 which was around 0.35% annually [3].

Even though automation positively affects society's economy, it negatively affects society's socio-economic structure. Naturally, if a company's productivity is increased, then so is its revenue. A company with profit seeking goals will most likely increase its density of industrial robot use to increase its productivity which will in turn increase profits. However, this increase in profits has a socio-economic cost. This is confirmed in the Graetz Michaels study that found an increase in industrial robot use decreased work hours for low-skilled and some middle-skilled workers [3]. This can bring corporate social responsibility on the company's part into question. Did the company choose productivity and profits over people's livelihoods? It doesn't help that the displaced workers were typically of a lower socio-economic status. MIT professors Erik Brynjolfsson and Andrew McAfee believe that rapidly advancing technology such as industrial robotics have caused the median income of Americans to plateau and the income gap to increase [4]. However, some people, like Robert Atkinson of the MIT Technology Review, argue that "historically, the income-generating effects of new technologies have proved more powerful than the labor-displacing effects…" [5]. People like Atkinson argue that this surplus of revenue is then used to boost the economy and eventually leads to overall higher employment. This perspective would lead one to believe that most large corporations with the capital to do so, would strive for "lights out" manufacturing plants. However, just this last year, many luxury brand automotive companies have decreased the number of industrial robots in their manufacturing process. This phenomenon is mostly due to the high priority of customization in the luxury automotive industry. Companies like Mercedes-Benz, BMW, and Audi have had to replace their mostly automated process with more human workers to meet the demands of customization [6].

Automation in manufacturing also positively affects the work environment and the global environment. One benefit of automation in manufacturing is that it prevents humans from being forced into dangerous work environments. This is beneficial to both the company and the employees as safety and risk mitigation are top priorities in manufacturing. Automation also can be environmentally friendly. This is especially true when "lights out" manufacturing is implemented fully. Without worrying about amenities for a human environment, a "lights out" manufacturing plant will use less energy [7]. Even outside of the "lights out" implementation, automated manufacturing increases efficiency in many areas that reduce a manufacturing plant's environmental footprint. These efficiency increases include waste reduction due to high accuracy and energy use reduction due to high speed [7].

Automation in manufacturing clearly affects our society's economy and environment in a beneficial way, while it affects our society's socio-economic structure in a harmful way. It seems that the negative effects on socio-economic structure are the most common reaction to automation in manufacturing. This issue of automation leading to lost jobs was by far more prevalent in news articles and is therefore a very pressing matter in our society. The news articles focused more on job loss, but there are some businesses that were born out the "lights out" manufacturing movement: Midwest Engineering Systems is a company that aids manufacturer's through the transition to "lights out" capabilities [2]. Whether automation's job-displacing power is an overall economic problem or not, people will always be concerned about unemployment on a personal level and as an economic metric. The change in socio-economic structure that automation causes is the kind of negative impact that creates cautionary literature like Phillip Dick's "Autofac" or provocative headlines in the news. When making decisions in science and engineering, it is important to think about the effects of these decisions and how they will affect society (socially, economically, and environmentally) as well as how society will perceive these decisions.

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Natural Gas for the Environment

Kenneth Larson

Times have changed for the electric power grid. As the world becomes more and more conscious of humanity's impact on the environment, the pressure to produce power in an environmentally friendly manner has grown dramatically. As a result, the power grid is now greener than ever before. New technologies and engineering advances have paved the way for a new, more diverse grid that is not only economically sound, but significantly more ecologically responsible. However, the basis of this ongoing green revolution is not formed exclusively by renewable sources. In fact natural gas, a fossil fuel, has paved the way for environmentally conscious energy. While renewable sources receive significantly more interest and attention, advances in power generation through natural gas have been a critical driving force behind the creation of a newer, greener power grid. Indeed, in today's power system, developments in natural gas-fired generation have been the single largest contributor towards creating a more sustainable and responsible power grid.

When attempting to improve the environmental responsibility of a process, the primary concern is typically reducing carbon emissions. Gasses such as carbon dioxide are known to trap heat in the Earth's atmosphere, thereby contributing to the climate change which has far-reaching consequences for our world. Since these gasses are a major byproduct of fossil fuel energy sources, the conventional wisdom is that reducing the use of fossil fuels is the quickest way to reduce greenhouse gas emissions. However, not all fuels are created equal. Currently, the two largest sources utilized for power generation are coal and natural gas. Each of these fuels accounts for roughly a third of America's power demands [1]. However, according to the US Energy Information Administration, coal is responsible for 71% of emissions related to electricity generation, whereas natural gas was only responsible for 28% of emissions [1].

The environmental benefits of natural gas as a cleaner burning alternative have long been known. However, recent advances in both the extraction and utilization of natural gas have made natural gas a more useful and economically viable option. For example, the development and improvement of dual-cycle plants, which use the waste heat from a gas turbine to generate additional power, has increased the efficiency of gas-fired power plants, reducing the amount of fuel required and, consequently, the cost of electricity generated by these plants. As a result of these and other engineering improvements, the economic cost of utilizing natural gas as a fuel source has dropped to competitive levels. As a result, natural gas has started to replace coal as a preferred energy source for electricity generation. Between 1985 and 2016, coal's share of electricity generation dropped from roughly 55% to 32%, while natural gas' share simultaneously rose from 10% to 33% by 2016 [2]. Natural gas produces roughly half of the carbon emissions of the Bituminous coal commonly used in American power plants [3]. As a result, over the past 30 years, the increased use of natural gas, spurred by improvements in both its extraction and use, has substantially reduced the overall amount of emissions produced in electricity generation.

Natural gas has another advantage compared to many other fuel sources in that it is substantially more flexible when implemented in electricity generation. In power generation, ramp rate refers to how quickly a source can adjust its output between various levels. This is especially critical in the power industry due to the highly variable nature of the demand for electricity. Throughout the day, the demand for power fluctuates significantly, with the overall need being significantly higher at certain times of day. A utility must be able to meet the requirements of the peak load time, despite the fact that the average daily load requirements will be substantially lower. This means that a power plant must either generate more energy than is needed for most of the day, resulting in an unreasonable amount of wasted energy, or adjust their power outputs throughout the day to try to match the load cycle. Natural gas plants typically have a comparatively high ramp rate. Most are able to vary their output by 15-25MW per minute, with newer, more advanced setups able to adjust at up to 50MW/min [4]. By contrast, typical coal-fired plants can only change by around 2-4MW/min [4]. Since coal-fired plants are slow to adjust, generation schemes that rely heavily on coal typically have more difficulty in adequately matching the changing daily demand, resulting in significant increases in wasted energy and, therefore, greenhouse gas emissions. By contrast, natural gas facilities, in particular the more technologically advanced modern setups, are able to flex their output more rapidly, meaning that they can more adequately match the changing demand curve and thereby waste less energy and release fewer greenhouse gasses. Improvements in technology and engineering practices with regards to gas-fired electricity generation have been a significant boon to the efficiency, and therefore environmental responsibility, of the power industry.

It may not come as a surprise that natural gas is significantly more ecologically friendly than traditional coal-fired sources. However, natural gas is significant in that it is not only an improvement on past practices, but a gateway to help implement other environmentally conscious energy sources. Any truly sustainable energy source cannot rely permanently on finite, nonrenewable sources such as fossil fuels, which have a limited supply and cannot be relied upon into the extended future. It is out of this argument that the push for renewable sources, such as wind and solar, has arisen. However, these sources are far from perfect, especially with regards to their implementation in a large grid system. One of the largest issues with sources such as wind and solar is that they are non-dispatchable. This means that they generate power based on current weather conditions, and cannot be relied upon to always provide adequate generation for the customers.

In order to implement a significant amount of renewable sources into the power grid, a system must be in place to make up the difference between electricity supply and demand during times of low winds or high cloud cover. Large scale batteries and other storage medium have been proposed, but are not currently advanced enough to be implemented in an environmentally and economically responsible manner. This is where natural gas has a significant role in the future of renewable technology. Because of the high ramp rate of natural gas turbines, they can remain idle when weather conditions are good, but can be called upon to quickly compensate when renewable sources are unable to meet the demand of the grid. It is no coincidence that the growth of renewable has been mirrored by a similar increase in the use of natural gas [2]. Indeed, the two have developed a somewhat symbiotic relationship. As improvements in engineering and technology have increased the penetration of natural gas into the electricity market, the overall power grid has become more flexible and therefore capable of implementing renewable sources. Likewise, as the push for green energy has resulted in growth in renewable sectors, the need for a reliable backup system has spurred the demand for gas turbine generators.

It is for these reasons that engineering advances in natural gas extraction and electricity generation have been a critical driving force behind the move towards a more sustainable power grid. These improvements have significantly lowered the cost of gas turbine generation, thereby allowing these facilities to replace far more polluting coal as an energy source in many situations. The flexibility of modern gas turbine installations also allows utilities to more closely match the shifting demands of their customers, reducing the amount of excess electricity that is generated and then wasted. Further, improved practices in natural gas generation have resulted in a grid that is more adaptable, a trait that is critical to the future implementation of renewable energy. Because of this, improvements in natural gas systems have been a driving force for environmentally responsible electricity generation.

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Taking Back the City

Madison Northrup

Consider the world's biggest cities. Some of the largest metropolises: Paris, Tokyo, New York City, Buenos Aires are separated by miles, languages, and peoples. But a staple shared by all is the heavy congestion the cities face due to increasing car use. It is as if gridded cities have become a vehicle themselves, simply for cars to get through. But this ease of access and transportation comes at a cost. Cars, in addition to increasing traffic, increase air pollution and human injury and causality. Barcelona, the second largest metropolis in the Catalonian region of Spain claims to have a solution to cars taking over cities. The Spanish city is creating superblocks (superilles in Catalan), nine square blocks in which traffic is contained on the perimeter and the interior roads are reserved for pedestrians, cyclists, and local cars. [5] Superblocks attempt to reduce car use and increase *people use* while improving environmental health and creating economic development.

Superblocks are not a new idea. First realized in the early half of the 20th century, urban planners originally used superblocks to split up cities into smaller residential units. In these areas, pedestrians and cyclists could get around the inner area, but found it near impossible to leave as cars began to dominate the surrounding urban landscape. [1] Modern city planners began to implement superblocks on grid-systems to create more foot-traffic friendly neighborhoods where cars could not travel. In Barcelona, superblocks are created by taking nine square blocks of a neighborhood and permitting through traffic only on the borders. (Figure 1) Inside, local vehicles may travel at 6 mph in one way loops so that no interior streets are through streets. [5] The interior roadways are redesigned with no separation between sidewalk and streets, increasing the space that city dwellers can enjoy.

The city's Urban Mobility Plan lays out six goals for superblocks. The aims are as follows: increase sustainable mobility (such as promoting cycling and walking and reducing noise and emissions), revitalize public spaces, promote biodiversity (use increased space to plant more vegetation), promote social cohesion (ensure facilities for activities, generating employment and encouraging inclusion), promote resource self-sufficiency (reduce energy use), integrate governance processes (involve citizens in projects). [6]

The creation of these superblocks happens in two phases. In the first phase, traffic patterns are adjusted and speed limits are altered. Phase two is more comprehensive and does more to change the cityscape physically and socially. In phase two, parking garages are built to eliminate curbside parking and the speed limit is further reduced. At this phase, urban planners intend for interior spaces to be fully integrated into a shared space, where cars, pedestrians, and cyclist coexist and there is more room for public activities. [6]

Barcelona has 50 of these superblocks planned for the central downtown city; if fully implemented, 60% of the city would be made into shared spaces, where 94% of the interior streets can be used by pedestrians. So far, $10.8 million has been allocated to the Urban Mobility Plan and six superblocks have been implemented to different stages of completion. The results thus far are promising. In the most mature of the completed superblocks (began in 2003), transportation patterns have certainly changed. Within the superblock, walking increased by 10%, cycling increase by 30%, and vehicle used by 40%. [2] Air pollution in the superblock and surrounding area has been reduced to safe levels and noise pollution is less than 65 dB (compared to New York City's average of 80 dB). [3] But it's not just the numbers that show the positive impact of the superblocks. Citizens have notice a cultural shift in which pedestrians spend more time outside and more time together. A surprising impact is the reduction of crime recorded by police in the areas. Overall, urban planners and Barcelona are considering the project a success thus far and are implementing more superblocks.

The project has not been without opposition. As discussed previously, the original rendition of superblocks created isolated neighborhoods wherein getting around was equally challenging for vehicles, bicycles, and pedestrians. Newer models show that retroactively implementing superblocks on grid-based cities more successfully reduces car use and increases use of public space, but the transition isn't always smooth. In Barcelona, where 50 superblocks are currently planned, opposition from locals is common in the first phase. Particularly, locals have raised flags about the lack of communication in the beginning stages of creating superblocks and residents and business owners are not given enough time or explanation to properly prepare before traffic patterns are adjusted. The result is an initial increase in local traffic, as confusion and frustration makes the duration of trips significantly longer due to the one-way loops and inability to traverse the entire nine square block. In addition, from start to finish, the process takes a few years and with the continuous construction, locals dislike the disruption to their neighborhoods. [4]

The aims of the superblocks are clear and the effects are overwhelmingly positive, but implementing it in the most effective way isn't always a reality. Long-term residents are resistant to change and improper communication makes changing not only the landscape, but the culture a challenge. With these difficulties in mind, Barcelona urban planners have first transitioned up-and-coming neighborhoods, such as an old industrial sector where the government built low-income housing, so that a majority of residents move into the superblock, as opposed to the block changing around current residents. [2] This approach helps gain support for superblocks and makes it easy to get a community on board with creating one in their own neighborhood. There is positive trend, though, even in opposition: as seen in the oldest Catalan superblocks, resistance decreases as the blocks mature.

Barcelona has seen success in improving the environment and quality of life in the city by implement superblocks. But can it work for other cities? Nearly all cities are looking to reduce air and noise pollution (New York City has experimented with shared streets to varying degrees of success), but with cultural implications of the project being so large, superblocks may not be the answer for everyone. One place U.S. cities may look for inspiration is universities and tech corporations, which implement the same principles of vehicle traffic around a perimeter with inner space reserved for pedestrians and cyclists on their campuses. [1] Colorado School of Mines, for example, is hoping to expand the “Pedestrian Plaza” to reduce car use on campus. Companies such as Google and Facebook have “campuses” featuring foot-traffic only areas as well.

Superblocks are changing the very fabric of Barcelona. Not only does data show that the superblocks are improving air quality and noise, cultural shifts are evident. The city is less about cars and getting around and more about the people living in them. Barcelona’s Urban Mobility Plan makes it clear that this was an intended outcome from the beginning and with good sense; one can expect to change how people behave without changing how people think. Engineering is often about effectiveness and efficiency in addressing a problem, but it is important to consider larger social context in which the problem exists. Cities hoping to reduce pollution should look to Barcelona, where the urban planners saw positive outcomes not from restrictions and bans, but by shifting their culture in addition to their streets.

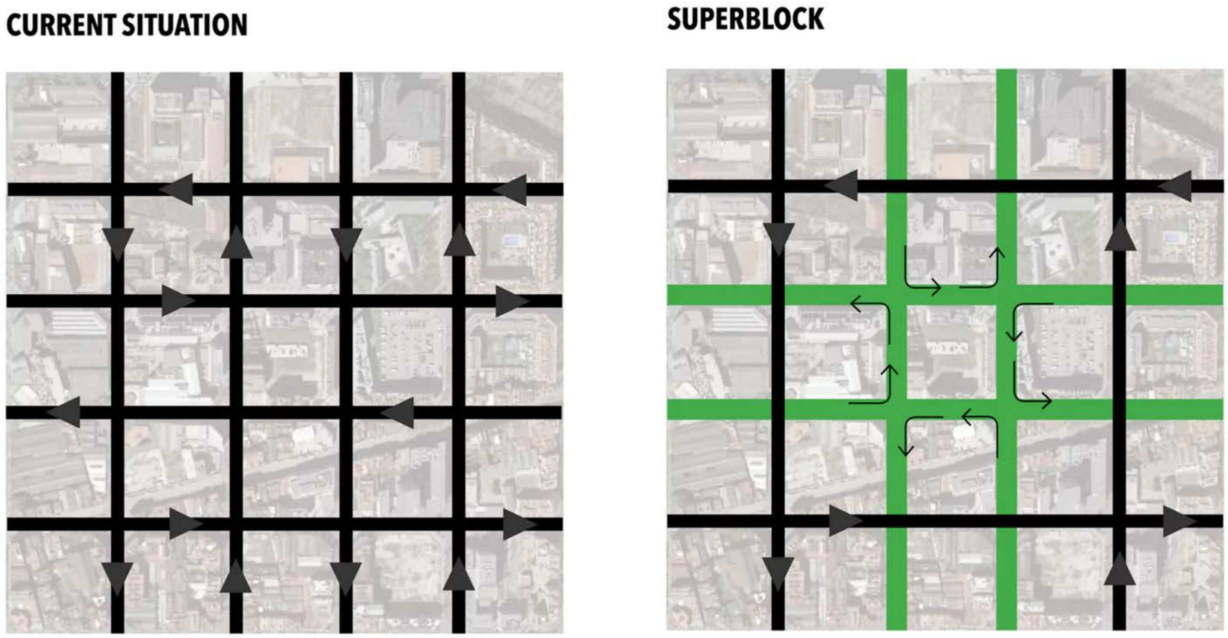

Figure 1: Current traffic pattern (left) and super block traffic pattern (right).

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Saying Goodbye to Farmer Bob

Logan Schuelke

In a classroom in Colorado, a professor pulls up a video of an autonomous car, raving at the progress that technology is making and extolling a future where a human need not be behind the wheel. Autonomous vehicles are, he proselytizes, the future. The subject he is teaching covers a field that has been created during his career. Yet now, these topics are nearly pop culture, with Google searches for autonomous vehicles showing exponential rises in search popularity in the last two years. [1] The future, as he sees it, is bright.

Hundreds of miles north on the South Dakota plains, an alfalfa farmer completes winter maintenance on an old tractor. Years ago this tractor and a section of land was enough to make a healthy profit, but now he fits repairs around driving a big rig, hauling gravel to make ends meet. He recognizes that the farmers like himself are struggling to stay relevant in the face of a changing industry. On the road he passes miles of tilled fields with empty houses, evidence of an industry where technology and large operations dominate. The future, as he sees it, is dim.

Hidden beneath fears of job losses in the transportation and industrial sectors lies the threat of a technological blight on our nation's farmers that threatens not only their jobs, but their culture. The plight of the farmer isn't new. The Jeffersonian vision of a nation of small farmers is long gone as the industry now accounts for less than two percent of jobs within the United States. [2] Today, advances in autonomous robotics threaten to disrupt this fragile industry in ways that few are preparing for. This impact stems from industry advancements that preclude significant negatives in terms of economic impact and cultural conflict.

As the computer revolution dawned in Silicon Valley, the results were quietly felt far inland with America's farm equipment. The widely implemented tractors of today are larger than ever before, include assisted driving (mainly drive themselves) and have automated maintenance alarms for everything from fuel lines to air pressures that must be serviced by your local company shop. Additionally, most systems are computer controlled, GPS guided, Wi-Fi enabled, and air-conditioned. [3] "The farmer can get in the cab, take a quick nap, and wake up to turn the tractor at the end of a row."[4] These technologies, along with numerous other methods of precision agriculture, have enabled huge productivity gains, but their impact is more limited then impending changes. The dawn of the IOT revolution led to a renaissance of connected technology R&D in the mid 2000's. Now the results of these investments are starting to come to market. These technologies range from drones to autonomous tractors, swarm robots, weeders, tillers, pickers, planters, harvesters, and more. For example, Case IH in 2016 launched its first prototype autonomous tractor, with industry estimates suggesting it will be released commercially by the end of the decade. [5] Autonomous solutions like Case's tractor are production ready for some specialty crops. Agrobot's strawberry harvester is accurate enough to assess the strawberries on a plant, determine which are ripe, harvest them during the best hours for picking (in the dark), weigh them, inspect them, and package them with no human intervention. [6] Harvest Automation's HV-100 greenhouse robot can redesign plant layouts for optimal growing and implement them with no outside prompting, optimizing space efficiency. A team of four of these robots can "space some 200,000 plants during peak shipping time without affecting labor availability". [6] Bringing a variety of these technologies together, the Hands Free Hectare project in England is growing a cereal crop to completion without a farmer ever stepping on the field, planting its first crop in March. [7] Together these technologies are so disruptive that a Goldman Sachs analysis estimates that they will create a 70 percent increase in per acre farm yields by 2050. [5] To say these technologies are impactful is an understatement, and their effect becomes clear with economic analysis.

Although these technologies portend huge productivity gains, they are currently not economically viable for many crops. Cost parity with human labor is expected by 2020, yet 10% of American producers have already implemented them due to scale efficiency. [8] Without having the needed scale, family farms have to cede to large operators the advantage of being first adopters. While small farmers are waiting for prices to go down, their competitors capitalize on the productivity gains from automation and gain a financial edge in the intervening years. According to the grower mentioned in the intro, this challenge is already being felt. "You have to be able to implement these technologies, or you'll just fall further and further behind the competition. Even if these technologies aren't more efficient today, they will be tomorrow, and I won't have them." [4] This effect will only serve to intensify the trend of ownership solidification in agriculture where the spreads of large owners get larger and small farmers sell out. Additionally, as productivity gains magnify and ownership scales increase, the number of operators needed will only continue to drop. According to Dr. Dwayne Beck, manager of the Dakota Lakes Research Farm at South Dakota State University, of the leading producers in the Dakotas, nearly all have started adopting some elements of precision agriculture, from self-steering tractors to yield mapping, and rates of adoption are only increasing. [9] To this point, spending on artificial intelligence in agriculture is projected to grow from 2016 values of $16.2 million to $373.7 million by 2024. [10] Even more tellingly, spending on agricultural robots in general is projected to increase from 32,000 units in 2016 to 594,000 units in 2024, or a market of $74.1 billion. [11] Ultimately, the current industry trajectory pledges to look a lot like the hope of Harvest Future, farms without farmers.

The future of farms as engineered systems is moving away from needing a farmer. As a result, the farmer as a culture is in significant danger of disappearing. This doesn't sit well with farmers who see the profession as their identity. In fact, analysts argue the implementation of autonomous systems will be slowed by operators who want to remain in the cab of the tractor, even if they don't need to be there. [3] Additionally, many operators doubt the abilities of the technology and argue that there is no way that a machine can understand the field as well as a trained farmer. [9] The notion that farmers are a noble profession that is dependent on traditional behaviors (sitting in a cab) and generational knowledge is widespread. The alfalfa farmer, Buccholz, argues that even if you do convince the farmer to finally leave the cab, he'll just go sit in a local coffee shop. "He's not going to go do something else with the time, cause he's still a farmer" he notes. [4] Yet, the dominant trends are certainly indicating that the farmers may quickly have to come to terms with the reality. On this point Dr. Beck argues that these technologies can be seen as beneficial if they allow farmers to spend that time outside the cab regaining intimate knowledge of their crops (as was the norm in older generations) that has been lost in the current age of air-conditioned mechanization. [9] Allowing farmers to have large scale understanding of their crop health from a metricized perspective; however, would require significant workforce reeducation, and resources that don't currently exist. In a defeated tone, Buccholz pleads "When you have guys that want to do the work themselves, why would you take that away from them with a machine?"

Due to issues of economics and productivity, the Pandora's Box of agricultural automation has been opened wide, and threatens the way of life for farmers on the high plains and across the country. Answers are few and far between. One approach is that of education for both the engineer and the farmer. Up into the first of my masters' classes on robotics, I've never had a professor address the ethical side of robotics design. Creating moments of intercultural praxis between the designer and the consumer will be vital if cultural concerns are to be even partly addressed in future technological advances. Furthermore, rural development programs should start retraining workers to address the impacts of this professional debasing. The dawn of the age of automation is rightfully discussed as a new industrial revolution. Ultimately, many of its negative impacts are unavoidable even with better design and policy, and society must prepare to address them. If we are willing to accept the fruits of this transformation, we need to be willing to care for its casualties.

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Impacts of the Tesla Model 3 on a Sustainable Future

Zachary Swanson

The Tesla Motors mission statement is placed prominently atop the about page on its website: “Tesla’s mission is to accelerate the world’s transition to sustainable energy.” [1] On March 31, 2017, Tesla took the next step in their mission by unveiling the Tesla Model 3 [2]. This release marked the beginning of the third phase laid out in CEO Elon Musk’s master plan for Tesla back in 2006: “Use that money to build an even more affordable car.” [3] Musk’s goal was to use the capital and popularity gained from the more expensive Roadster and Model S to engineer an electric vehicle for the masses. While affordable, the Model 3 missed the target when it comes to Tesla’s overall mission statement of sustainability.

The appeal of electric vehicles is that they release zero carbon dioxide when driven. However, Tesla still relies on fossil fuels, both in the production of their cars and the production of the electricity for the grid [4]. The use of fossil fuels early in production makes the carbon footprint of electric vehicles higher than standard vehicles before they even touch the road. The National Center for Policy Analysis states “It costs 30,000 pounds of carbon-dioxide emission to produce an electric car, equal to about 80,000 miles of travel, yet it's only 14,000 pounds to build a conventional car.” [5] The use of heavy equipment to mine the lithium used in the batteries is just as unsustainable as drilling for gas, if not more. The Devonshire Research Group states “The extraction of lithium has significant environmental and social impacts, especially due to water pollution and depletion.” [6] As Model 3 production increases, so will the demand for lithium. While arguments can be made that the mass production of electric vehicles will make the process more efficient, there will still be a net increase in volume of carbon emissions as more lithium is mined. On top of the larger production carbon footprint, the lifecycle carbon footprint of zero emission vehicles is also non-zero. The main source of electricity generation in the United States is fossil fuel. In 2015, approximately 67% of the United States’ electricity was generated with natural gas, coal and petroleum. 33% of the total electricity was generated with coal [7]. Even though Tesla’s Model 3 produces zero emissions while driving, the car still has a non-zero overall footprint. Ken Caldeira of the Carnegie Institution for Science claims that “When a wire is connected to an electric vehicle at one end and a coal-fired power plant at the other end, the environmental consequences are worse than driving a normal gasoline-powered powered car.” [8]

It could be argued under normal circumstances that Tesla is not at fault for the overall system in which their cars are sold. As a car company, they are not responsible for changing how the United States produces power. However, Tesla held itself to a higher standard. In the same 2006 master plan in which he laid out the foundation for creating an affordable electric car for the masses, Elon Musk stated another goal for his company: "While doing above, also provide zero emission electric power generation options." [3] For years, Tesla continued to "to focus on innovation and growth at the expense of profits." [9] However, with investors on their case, Tesla has needed to turn their focus toward making money [9]. That is where the Model 3 fits in. Tesla has needed to compromise on their mission statement to continue work toward staying afloat. While it is a step in the correct direction, the focus of Tesla on the Model 3 has done little to change the infrastructure environment in which it must exist.

The Model 3 was supposed to be Tesla's crowning achievement, and in a way, it was. The initial reaction to the Model 3 was great excitement. In the first week alone, Tesla received over 325,000 reservations, each at the price of $1,000 [10]. The excitement for the Model 3 was good news for the company as well, as shares jumped up 3.3% overnight [11]. The surge in excitement seemed to indicate that more people were interested in purchasing electric vehicles. Sales data however, refutes this point. As the excitement built for the new Tesla model, sales of other electric vehicles decreased. The Nissan leaf was the most affected, with sales declining 39% in May 2016 over the same period in 2015 [12]. General motors halted production on the Cadillac electric vehicle, instead focusing on the lower price Chevy Bolt [13]. With the unveiling of the Model 3, Tesla convinced buyers to wait to upgrade to an electric vehicle. They are estimated to start shipping in late 2017 [14]. The announcement of the Model 3 has actually decreased the rate of electric vehicle purchases. This effect is even more pronounced with lower gasoline prices. People do not feel the need to upgrade to a zero emissions vehicle when the price of gasoline is so low [15]. While the increase in market control is good for Tesla and its shareholders, it flies directly in the face of the mission to "accelerate the world's transition to sustainable energy." In fact, the large time difference from unveiling to shipping is decreasing the rate at which drivers switch to electric vehicles. This is a result that goes against Tesla's mission statement. In 2014, Tesla took steps to get better electric vehicles on the road faster. They stopped enforcing the patents they owned so that other companies could use the same technology to develop their own electric vehicle programs [16]. It was seen by many as a selfless act, especially because it went against the interests of the company's profit. This was Tesla Motors trying to accelerate the world's transition to sustainable energy. The early unveiling of the Model 3 was not. Whether intended by Tesla or not, the Model 3 release changed the landscape of the electric vehicle market permanently.

Tesla's announcement of the Model 3 was declared by many as a commercial success, and a sign of the beginning of the end for gasoline vehicles. In the short term, however, the promise of the next generation vehicle has stalled the progress of the current generation. The release of the Model 3 slowed the conversion rate of drivers to electric vehicles, and the reliance of electric vehicles on a coal based energy infrastructure reduces the impact of current zero emission vehicles. Tesla's approach to the Model 3 succeeded at increasing the sustainability of the Tesla Motors, but failed to increase the sustainability of the world.

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