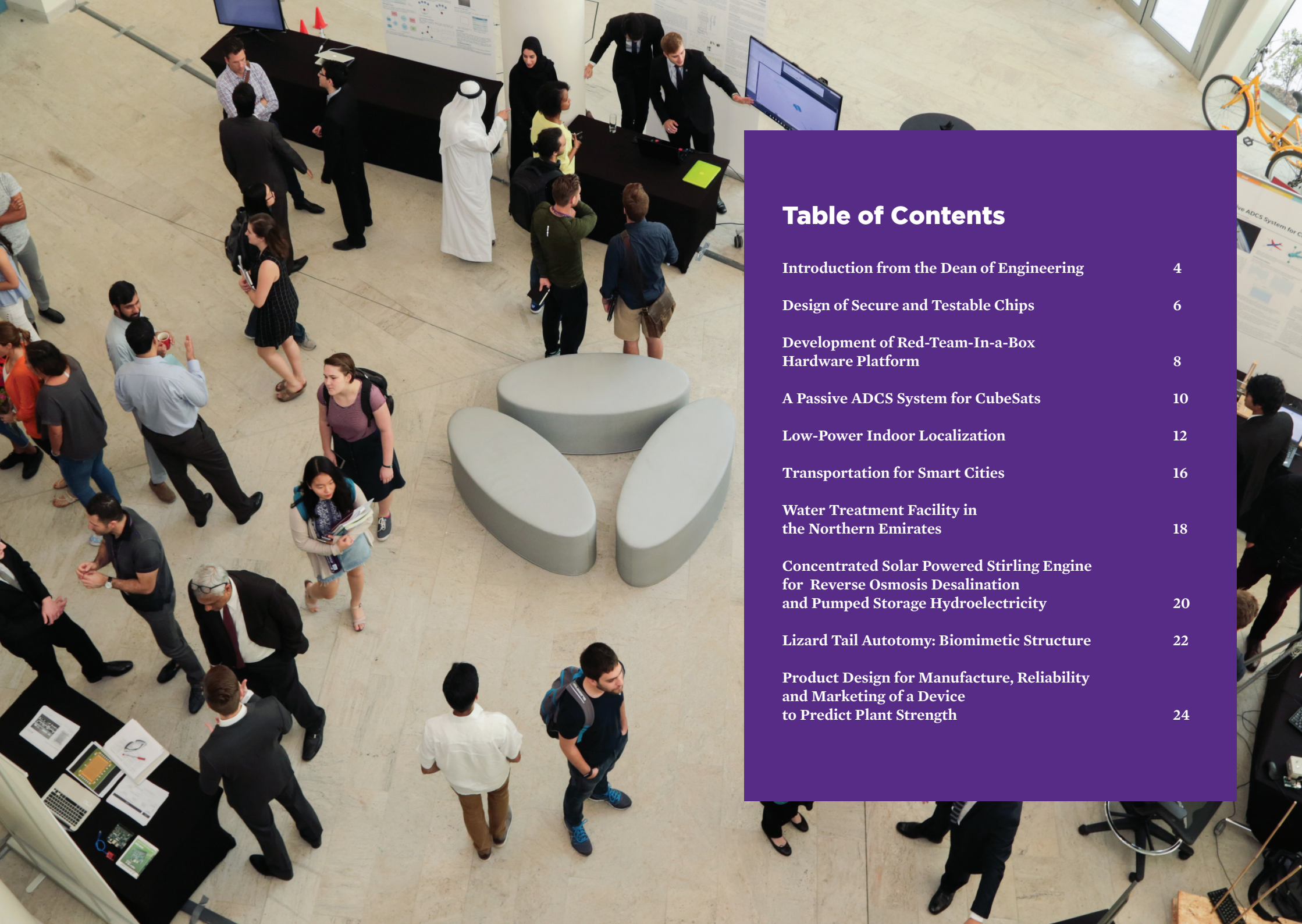
ENGINEERING CAPSTONE PROJECTS

CLASS OF 2017



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Introduction from the Dean

The Fourth NYU Abu Dhabi Engineering Capstone Festival held on May 7, 2017 at the Engineering Design Studio was a platform for our Class of 2017 Seniors to showcase their year-long Capstone projects using design solutions to solve real world problems.

The Capstone Design Course provides a major design experience leveraging the knowledge and skills acquired throughout the four-year curriculum. Structured to immerse students in the process of design with measurable standards and multiple realistic constraints, projects address engineering and technology topics and design innovative engineering-based solutions following the examination of multiple project parameters. The Capstone also provides students with an opportunity to integrate technical, human, aesthetic and business concerns with applied design solutions.

This booklet celebrates only a small piece of the Seniors' imaginative and innovative projects and which also align perfectly with our Engineering Research Priorities as follows:

In Cyber Security, our students designed *Secure and Testable Chips*, developed a *Red-Team-In-a-Box Hardware Platform* and developed *A Passive ADCS System for CubeSats*

In Future Cities, they designed a *Low-Power Indoor Localization* system appropriate for quadcopters to produce a stable decentralized network; and an approach to infer traffic parameters from fixed and mobile data in *Transportation for Smart Cities*

In Environmental Sustainability, they developed a project on a *Water Treatment Facility in the Northern Emirates*; and a *Concentrated Solar Powered Stirling Engine for Reverse Osmosis Desalination and Pumped Storage Hydroelectricity*

And in Bioengineering, topics ranged from *Lizard Tail Autotomy: Biomimetic Structure* to *Product Design for Manufacture, Reliability and Marketing of a Device to Predict Plant Strength*

Congratulations go to our Class of 2017 Engineers as they graduate from NYU Abu Dhabi to take on real world challenges and opportunities! With our very best wishes for a wonderful journey ahead,

Sincerely

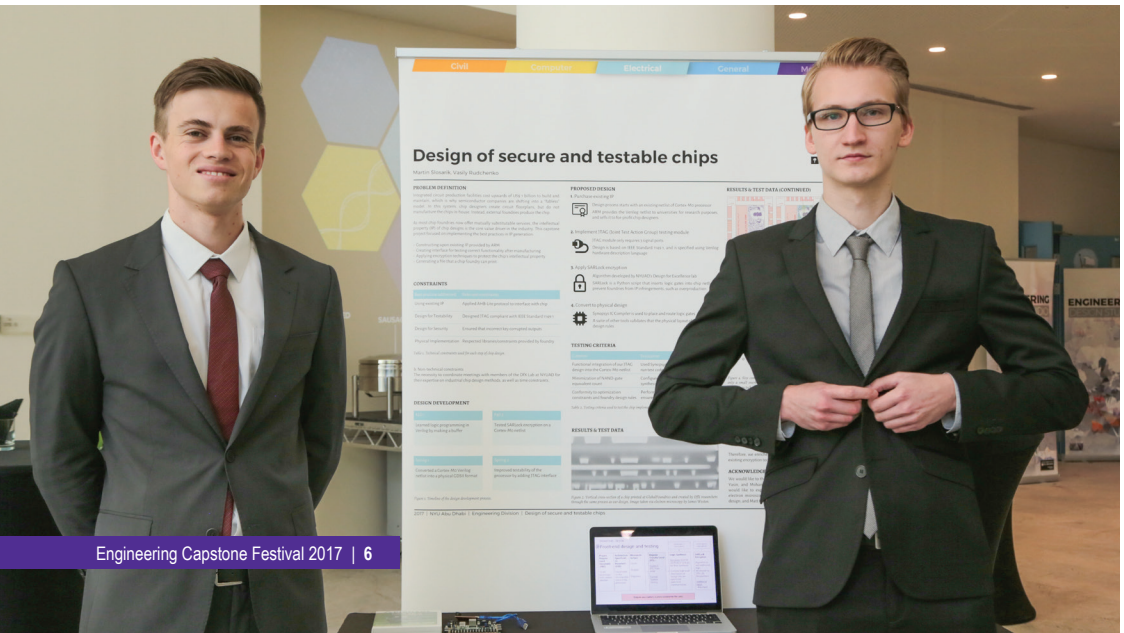
Samer Madanat
Dean of Engineering, NYU Abu Dhabi

Martin Slosarik and Vasily Rudchenko

Design of Secure and Testable Chips

Integrated circuit production facilities cost upward of US$ 1 billion to build and maintain, which is why semiconductor companies are shifting into a cheaper “fabless” model. In this system, chip designers create circuit floorplans, but do not manufacture the chips in-house. Instead, external foundries produce the chip. The purpose of the capstone project was to conduct an implementation from the register transfer level (RTL) to silicon, while addressing concerns that arise from the shift toward outsourcing of fabrication.

As most chip foundries now offer mutually substitutable services, the intellectual property (IP) of chip designs is the core value driver in the industry. Thus, the project focused on integrating new functionalities with an existing design of an ARM Cortex-M0 chip, instead of starting the chip creation process from the beginning. To ensure that the chip is easily testable after manufacturing, we enriched the Cortex-M0 with a JTAG test module for functional and scan chain testing. Providing the chip design to foundries around the world raises concerns about illegal chip printing and tampering with the design. We applied the



SAT Attack Resistant Logic Locking (SARLock) logic encryption method, which is necessary to prevent overproduction and insertion of Trojans at untrusted foundries. SARLock added an extra layer of security over typical logic encryption to ensure that the chip can only be decoded with a brute-force attack. Lastly, we conducted rigorous physical implementation. Chip printing is expensive, and the foundry only accepts new designs at specific dates, so a mistake in physical implementation can be costly and lead to major delays. Therefore, we implemented the physical chip from the RTL description of the ARM Cortex-M0 Microprocessor to the GDSII format.

The encrypted RTL was synthesized with Synopsys Design Compiler into a netlist. The implementation was simulated with Synopsys VCS to verify correct functionality, and verified using Nexys 4 FPGA. The tools to perform the back-end design were Synopsys IC Compiler for placement and routing, Star RC for RC extraction, and PrimeTime for timing analysis and PrimeRail for power network verification.

Capstone Supervisor: Ozgur Sinanoglu, Associate Professor of Electrical and Computer Engineering

Pablo Daniel Pacareu Olmedo and Pedro Gaizka Zufiria Gerboles

Development of a Red-Team-in-a-Box hardware platform

The modernization of critical infrastructure has enabled advanced monitoring and control capabilities, through the inclusion of microprocessor computing systems using commercial-off-the-shelf integrated circuits and commonly used protocols. Therefore, these systems are susceptible to cyber-attacks. The aim of the project was to identify possible entry points in order to fortify said systems. An advanced sensing platform was developed, which could facilitate physical penetration testing of industrial control systems. The platform had its own processing capabilities and operated on a battery in order to achieve autonomy. The sensors used were integrated on a custom-built PCB. The goal was to maximize the information collected by the platform, while minimizing the power consumption and the cost. The resulting platform was able to fingerprint industrial devices, eavesdrop on communications and collect other information needed to generate a detailed map of the surrounding environment of the industrial control system.

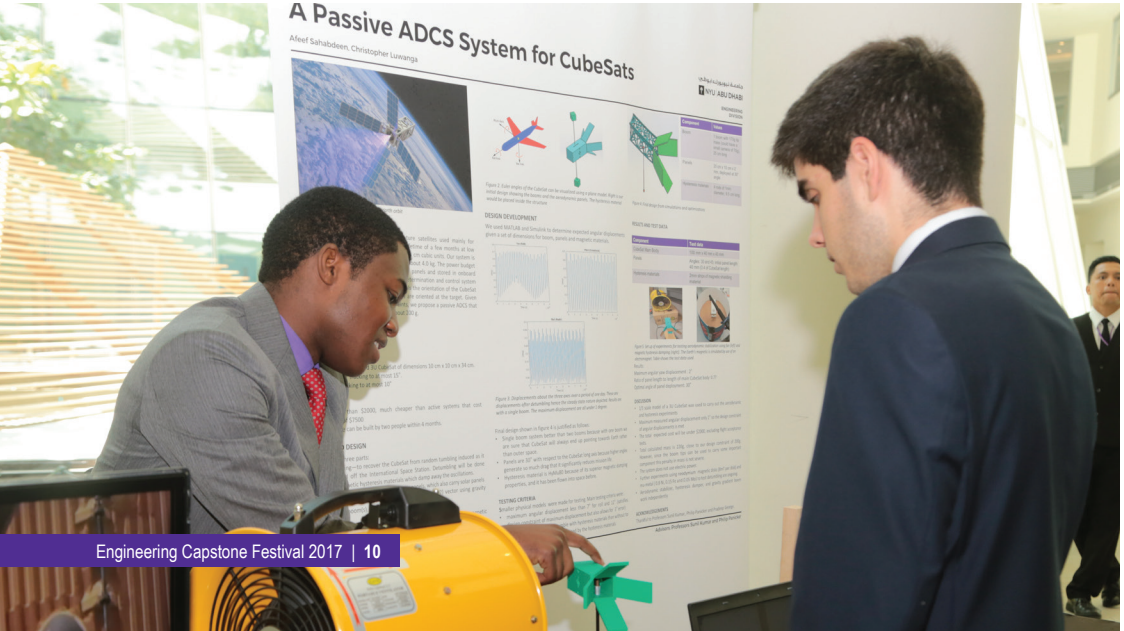
Capstone Supervisor: Michail Maniatakos, Assistant Professor of Electrical and Computer Engineering

Afeef Sahabdeen and Christopher Luwanga

A Passive ADCS System for CubeSats

One of the main constraints with CubeSats is that of power. An Attitude Determination and Control System (ADCS) is just one of the many systems that may require power to operate. We designed an ADCS that does not use power at all, but is solely based on the laws of physics and mechanics. Each of the three methods described here have been used on larger satellites, and on a few recent CubeSat missions. However, most of the satellites that used some passive stabilization system used it secondarily or at least with some active stabilization systems that can be turned off.

For our project, we used entirely passive methods. By manipulating the geometric, mass, and magnetic properties of the CubeSat, the CubeSat can be designed to auto-correct its attitude. We analyzed aerodynamic forces, magnetic hysteresis materials, and gravity gradient booms for use in controlling the attitude of the CubeSat. However, only the use of gravity gradient booms (GGB) to align the CubeSat length with the nadir vector is demonstrated in most detail in this project. The GGB method only requires a calculated mass distribution in order to stabilize the system. For the aerodynamic forces design panels deploy on the (-Z face) faces, and the panels act like airfoils generating stabilizing torques as well increasing drag on the satellite. Increasing drag is also useful because it increases the rate of CubeSat orbital decay; NASA estimates that over a third of CubeSats may stay way too long after their mission such that they pose a space debris problem. By using this panel deployment system, we can hasten the orbital decay and allow the CubeSat to deorbit quickly. Further, the design resorts to magnetic hysteresis materials to eliminate the spin of the CubeSat by taking kinetic energy of the spinning CubeSat out through hysteresis losses. The ferro-magnetic materials can be magnetized by the earth's magnetic field thus no current is consumed for this process.



Capstone Supervisors: Sunil Kumar, Professor Mechanical Engineering and Philip Panicker, Senior Lecturer Mechanical Engineering

Hassan H Nahas and Asfandyar Sirhindi

Low-Power Indoor Localization

Localization is the process of locating a node in a network through the use of anchors, points with a predetermined and known position. Various techniques exist and are employed depending on the desired accuracy and available resources. These include Received Signal Strength (RSS), Time of Arrival (ToA), Time Difference of Arrival (TDoA) and ToA-Angle-of-Arrival Hybrid. The problem of localization poses a computational challenge, particularly in low energy systems with a large number of nodes. Mathematical tools are being developed to tackle this challenge including Randomized Extended Kaczmarz.

The purpose of this capstone is to design and implement a localization system appropriate for an indoor system of robots to produce a stable network with decentralized processing. To do that it will be important to minimize the number of computations necessary, making mathematical tools like Multidimensional Scaling, Multilateration and Randomized Extended Kaczmarz important, especially when dealing with the uncertainties of the real system. Range-finding technology based on Ultra-wideband (UWB) technology will be used to obtain the distances between the nodes. Localization will then be decentralized allowing for cooperative localization to help identify tags further away from the anchors.

Capstone Supervisor: Nikolaos Freris, Assistant Professor of Electrical and Computer Engineering

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Monika Filipovska

Transportation for Smart Cities

Transportation for smart cities, significantly based on modern data science and traffic analytics, is a field almost entirely dependent on the availability of accurate knowledge of real-time traffic conditions. Accurate data representing real-time traffic conditions is necessary for performing real-time traffic analytics, whose applications can range from network-wide signal control, real-time trip planning and forecasting, to traffic incidents response. However, traffic analytics is often encumbered by the fact that real-time data is typically unavailable for large portions of the urban networks at any given instant. Thus data is discontinuous, interrupted and quite sparse to reflect the real-time traffic state to be useful for any real-time applications. Therefore, urban traffic state estimation has become the core challenging problem for practitioners and researchers in the field.

The goal of this capstone work was to identify and calculate spatio-temporal correlations in traffic flow that can be used for real-time traffic state estimation. The project focused on developing a model for real-time traffic data reconstruction that allows for using the sparse data from instrumented road segments to accurately estimate the traffic conditions for

segments that lack instrumentation. This model is based on available complete data from sensors that do not provide real-time sensing, to be applied onto sparse real-time data. The main focus of the project is performing data reconstruction for a single, simple, isolated road section that can further be expanded to fit complex road sections or traffic networks. This project is grounded in the idea that an approach based on probabilistic graphical models such as Markov Random Fields (MRF) would be a natural fit for traffic state estimation (TSE). The proposed approach is an MRF-based model that captures traffic conservation laws and traffic correlations and allows for traffic state estimation. The model is expected to perform in real time, that is, in under one second, and provide accuracy with an error lower than the current benchmark for TSE approaches, which was established at 6.7% calculated as Mean Absolute Percentage Error (MAPE).

Capstone Supervisor: Saif Jabari, Assistant Professor of Civil and Urban Engineering

Paul Ha, Maryam Al Mansoori and James Gardner

Water Treatment Facility in the Northern Emirates

The Northern Emirates faces unique and challenging water resourcing; with some of the most limited availability in ground water, and a water usage of twice the world average at 550 L per person per day, the UAE must have highly efficient waste water recycling systems. This project outlines a detailed design of a recycled wastewater treatment facility treating 225,000 m3 of water per day located in the Northern Emirates of the UAE. The scope of the design includes the water treatment process, structural housing, and road access ways with parking facilities. This Capstone included design drawings and analysis alongside project management methods undertaken to complete the project. The design chosen is a multistage water treatment process modelled on a traditional sewage treatment plant; wastewater undergoes primary, secondary and tertiary treatment in the form of coagulation, flocculation and sedimentation, a plug flow reactivated sludge line, and dual media filtration plus UV treatment. These processes were selected as best practices across the industry. Treated water is at a standard to allow for restricted irrigation as per the Dubai Municipality codes. This water is ready for distribution and use for irrigation in non-raw crops and landscaping. Designs were carried out in accordance with the Abu Dhabi Municipal Standards, the Dubai Municipality Standards, Environmental Protection Agency (EPA), American Society of Civil Engineering (ASCE), the American Concrete Institute (ACI) and the American Institute of Steel Construction (AISC) codes.

Capstone Supervisor: Khaled Shahin, Senior Lecturer Civil Engineering

Tshering Gyaltshen, Jean Nyaguthii Edwards and Said Siderite Abdallah

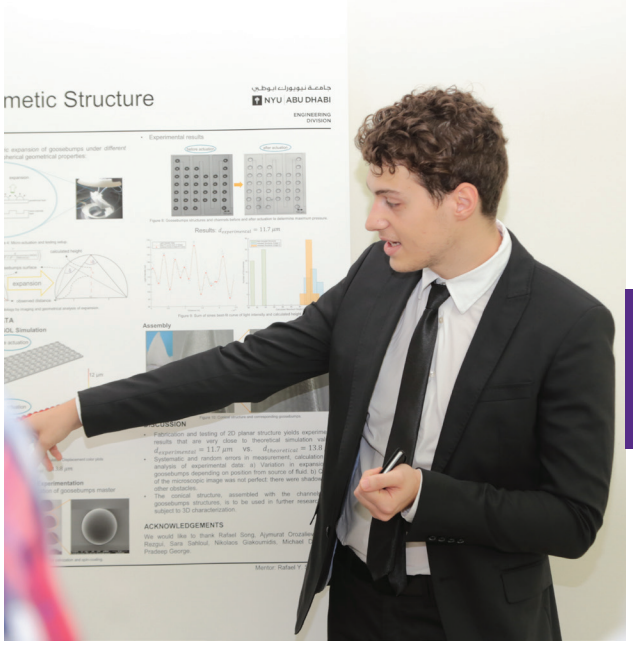
Concentrated Solar Powered Stirling Engine for Reverse Osmosis Desalination and Pumped Storage Hydroelectricity

Energy systems play a principal role in social and economic development, as well as welfare of the people, from grassroots all the way up to the global level. In recent years, there has been a rise in demand of renewable energy. This has led to an increase in research in this field, to come up with new innovative ways to satisfy this need. The most common form of renewable energy is solar energy, which is tapped by converting the sun's rays of light into electric or thermal energy. It is the cleanest and most abundant form of renewable energy. Furthermore, in most parts of rural areas, there is a limited availability of fossil fuels such as petroleum and electricity whilst there is a high demand of water for household needs. Although, countries like the United Arab Emirates where the access of petroleum is not a problem, they still need to find alternative ways to pump water in the rural areas because of the negative environmental impact of non-renewable energy sources such as the emission of carbon gases.

The purpose of this project was to develop a Solar Stirling Engine Pump that will use solar energy as the power source. Furthermore, in the bigger picture the project looked at the solar desalinization by using reverse osmosis, pumped storage hydroelectricity, and electric generation to sustain the pump. It focused on a new innovative way to capture solar energy, and applied existing Stirling engine technology for optimal results.

The Pumped Storage Hydroelectricity (PSH) will be performed along the Hajar mountains in the UAE. Two Francis turbines were used in the process each having a capacity of 55MW. The height of the upper reservoir is 100m having a length of 300m. The energy from the PSH will be used in peak demand period in the UAE. On the other hand, the Reverse Osmosis (RO) desalination of a spiral membrane was chosen with a plunger pump proving the high pressure of about 70 bars. For the Energy Recovery Device (EDR) the Francis turbine was the best candidate, which will help to recover about 40% of the energy that will be fed back to the incoming sea salt water.

Capstone Supervisor: Philip Panicker, Senior Lecturer Mechanical Engineering



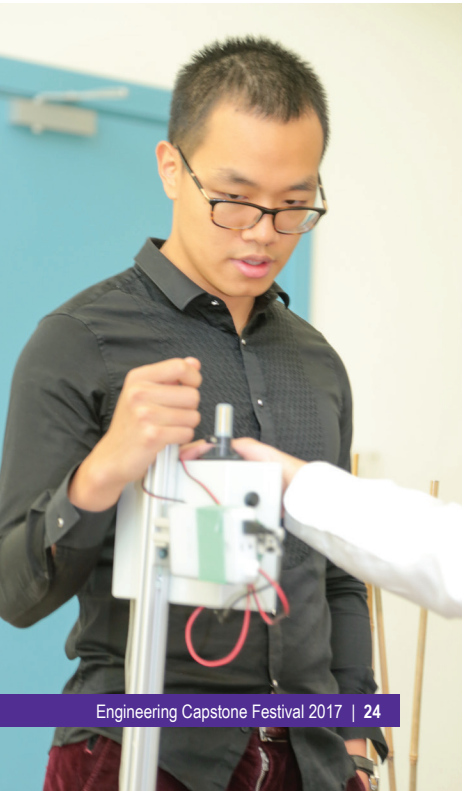
Hind AlTantawi and Vasko Lalkov

Lizard Tail Autotomy: Biomimetic Structure

Autotomy is the process by which some lizards detach part of their tails to distract predators when they feel threatened. These lizards often have aspects that draw a predator's attention, such as being brightly colored, having sharply contrasting colors or patterns, or a moving tail when the lizard is otherwise still. Lizards that can detach their tail have "fracture planes" spaced regularly down the length of the tail that are either between vertebrae or in the middle of each vertebra, depending on the species. It is at these specific planes on the tail that autotomy can occur. Skin, muscles, blood supply, nerves, and bone separate when the tail is dropped. After it falls to the ground, the tail starts to flex on the ground, giving the lizard a chance to escape while the predator is focused on the moving tail. This design project is dedicated to producing a biomimetic structure replicating the process of lizard tail autotomy.

To achieve this biomimetic task, the microstructure of goosebumps-like sheets was firstly designed and fabricated. Next, a triangular structure like that patterning the fracture planes in lizard tails was fabricated and assembled. Finally, the actuation of the planar structure was realized and used to numerically characterize the prototypes and the three-dimensional triangular structure was assembled for further research.

Capstone Supervisor: Yong-Ak (Rafael) Song, Assistant Professor of Mechanical and Biomedical Engineering



Witold de la Chapelle, Xiao Lu and Ting Che Lin

Product Design for Manufacture, Reliability and Marketing of a Device to Predict Plant Strength

The objective of the Capstone was to substantially improve, through two iterations of designs and improvements, the prototype device that measures crop strength. The first iteration of the device was designed during the first semester and tested in the field. Based on the feedback of the first iteration, the second iteration of the device was designed and built. Able to measure crop strength accurately, the improved device allowed for greater confidence in assessing the data. With an intuitive graphical interface, the device enabled a faster rate of data collection. An ergonomic handle allowed users to perform measurement without bending their waists, thus reducing the risk of musculoskeletal disorders and further improving data quality. A minimalistic design with rugged buttons contributed to the robustness and lifespan of the device. The improved device will allow farmers to breed more robust crop varieties and reduce wind-induced crop failures that cost billions of dollars of losses annually.

Capstone Supervisor: Douglas Cook, Assistant Professor of Engineering

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