

## Fall 2020 Senior Design **Virtual Showcase** Dec. 3-4, 2020

Featuring 100+ engineering and computer science projects designed by collaborative teams of graduating seniors of the UCF College of Engineering and Computer Science.

See videos of all team projects on our [Senior Design Virtual Showcase website](https://www.cecs.ucf.edu/SeniorDesignShowcase/showcase)  
<https://www.cecs.ucf.edu/SeniorDesignShowcase/showcase>

More than 90 alumni judges – now engineering and computer science professionals – will score the projects on a variety of metrics, provide qualitative feedback to the teams, and decide the best in each discipline and Best in Show.

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## Fall 2020 Senior Design Project Summaries

# Interdisciplinary Design Teams

### **Cloud Tracking V2 for Orlando Utilities Commission**

*Computer Science, Mechanical Engineering*

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### **Stormwater Drain Robot for UCF Utilities and Energy Services – Black Team**

*Computer Science, Mechanical Engineering*

Custom-made for UCF, these inspection robots can traverse stormwater drains and tunnels to identify blockages and cracks in the pipe walls, and record locations that require attention. Designed to complement existing resources in use at UCF, such as detailed maps and geo-location software. All software is kept within the robot's onboard computer. It exports files that are compatible with existing mapping software. Could be used in other industries.

### **Stormwater Drain Robot for UCF Utilities and Energy Services – Gold Team**

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### **3D Interactive Planogram Design App for Closet Maid**

*Computer Science, Mechanical Engineering*

The purpose of this project is to develop an application for AMES - ClosetMaid capable of constructing and displaying virtual planogram designs. Improves upon the current physical mockup system that is extremely time and cost consuming. This team's application is built in the Unreal Engine as a tool for non-technical users to easily construct designs and view them in VR. ClosetMaid staff can use this tool to present retailers a VR model of their planogram designs.

### **Blending Optimization for Coca Cola**

*Computer Science, Electrical Engineering*

The sponsor's blending process for drinks is complex and contains many varying components. The intricacy of the process exceeds the capabilities of manual management as it continues to grow. This solution automates and streamlines the schedule generation process. Given a macro-schedule of juice orders, this system produces a micro-schedule for equipment on the blending side of production. This system will make scheduling easier, simpler, and more efficient by exploring configurations and accounting for constraints that could easily be missed by a human in a system so complex.

### **"SimSpace" Advancing Urban Logistics - Red Team**

*Industrial Engineering, Biomedical Sciences*

Delivery companies, with large fleets delivering to hundreds of different locations, continually seek solutions for the "vehicle routing problem" (VRP), particularly in the "last mile" delivery phase, where finding optimal routes is difficult. This team has proposed using agent-based simulation to provide a visual representation of the most efficient vehicle routes. Agent-based models simulate the actions and interactions of autonomous agents while assessing the effects of the system. The team created a model that simulates an optimization experiment of transporting goods – from manufacturer to recipient – demonstrating how this software can solve VRP.

*(continued)*

## *Interdisciplinary Design Teams continued*

### **Laser Guitar**

*Computer Engineering, Electrical Engineering, Photonics*

An affordable instrument that plays like a guitar with lasers as the strings: a polyphonic device providing a new and innovative way to play music. Currently several models of laser harps and optical theramines exist, but laser guitars have not been extensively explored outside of this project. The device is a low-cost instrument that plays gives the user an experience similar to playing a real guitar.

### **Automatic Feed and Sanitizing Dog Bowl –Group 11**

*Computer Engineering, Photonics*

A cost-effective smart portioning and UV cleaning dog bowl. Cleaning the bowl in between use keeps the area fresh and protects pets from spreading disease like kennel cough. A product compact enough for use in homes, boarding facilities, and indoor dog parks. Designed to be easy to fill with food and water, with safety measures to eliminate risk of electric shock while filling the bowl with water. To track the pet's habits and overall health, a camera feature has been integrated with facial recognition software to help determine food/water intake of each pet.

### **Ultrasonic Bubble Popper**

*Computer Engineering, Electrical Engineering, Photonics*

Air bubbles inevitably occur when culturing cells in science labs. If many air bubbles are present in a solution, it becomes increasingly difficult to see cells under a microscope and allows for potential culture contamination. This project uses short ultrasonic pulses to pop such bubbles. Petri dishes can be inserted directly to have all air bubbles popped. Research indicates that the frequency of these short ultrasonic pulses matches the resonant frequency of most air bubbles and is also not damaging to healthy human cells. Useful for all biological labs that consistently culture cells in various media solutions with a preference for all cell culture containers to be bubble-free prior to storing.

### **AUDIOVISIBLE: An Audiovisual Spectrum Analyzer for an Underserved Audience**

*Computer Engineering, Photonics*

Aside from actual paintings and videos, there is no existing form of art intended to cater specifically to people who are deaf or hard-of-hearing. People who are blind can hear music and can feel the textures of risen-surface artworks; deaf people can see paintings but cannot generally feel sound. Although they can feel lower frequency vibrations if they are amplified enough, deaf people are virtually incapable of perceiving something that many hearing people consider to be a necessity in their lives: music.

### **Portable Device for UV Sanitation of Water “PUVC”**

*Computer Engineering, Electrical Engineering, Photonics*

This system uses ultraviolet (UV) radiation to sanitize water, making it drinkable, with UV lamps and diodes which produce the wavelength and power intensity needed to deactivate and kill bacteria. The system inputs water with a water pump into a main tank, passing through a filter to remove larger impurities. Then the UV light micro-cleanses the water. The user draws water from the tap. UV cleaning is verified with a simple test that produces a color change, which is determined by analysis with an RGB spectrum. The device is monitored through a web interface hosted on a microcontroller. Quality verification is performed in a separate chamber. Within 24-48 hours the sample will turn green if coliform bacteria is present, or remain yellow if not present. Inside the water quality analysis tank is a microchip, a RGB LED and a CdS photocell. During use, the MCU reads multiple sensor values and posts them to a Graphical User Interface, which can be accessed through any WiFi enabled device. The PUVC is powered with a wall outlet or a rechargeable battery. The PUVC is designed to be portable by two people with ease. Small and lightweight: will not cause significant burden on aircrafts or boats.

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## *Interdisciplinary Design Teams continued*

### **SolarPowered UV Water Filtration and Monitoring System**

*Computer Science, Electrical Engineering, Photonics*

Adds data collection, water analysis and monitoring in water filtration designs, which could be used commercially or at home. The entire project has four main systems. The solar power system has two solar panels providing off-grid operation and battery charging capable of running the system 6-8 hours without sunlight. The filtration system cleans the water flowing through the system, with one sediment filter, one carbon filter, and one ultraviolet filtration chamber. The water analysis system has a Raman spectrometer which detects (or ensures absence of) certain metals and organic matter in the water. Finally, the user interface takes the data from the spectrometer and displays water quality, and gives the user control to turn on or off the system. Spectroscopy is a high-quality way of analyzing and detecting different contaminants in water, which many filtration systems do not offer.

### **Laser Subsurface Etching**

*Computer Engineering, Electrical Engineering, Photonics*

With this project, users can etch 2D and 3D images into glass cubes. To achieve this, a high-power laser is pulsed into BK7 glass cubes, pulsing at specific locations inside of the glass to create the etching effect. For proper ablation, an Nd:YAG laser is used, which has high peak power with a beam that can be tightly focused. A microcontroller along with stepper motors control where in the glass will be lased. The microcontroller also interfaces with the laser to control pulse firing. The end result is a subsurface glass etching system that costs significantly less than other commercially available options.

## Computer Science

### **“MiSu Home” Android App for Smart-Device Management**

Centralizes the management of smart home devices, and enables sharing the devices with others safely and securely. Leverages Mozilla’s Web of Things framework. Device owners can use the app to select which devices others have access to, and what actions they can take. Users can set permissions, usage schedules, and more. This app offers more customization over what is available in the marketplace.

### **Autonomous Drone Laser Tracking System**

Uses a camera and laser to detect and track a drone that acts as a threat. The automated laser turret will aim at the threat drone and “shoot” it down. The technology is used by military defense. Overall system uses OpenCV, raspberry pi, Arduino, IR LEDs and receivers, and other components. Can be adapted to track other objects, such as cars.

### **“Divie” Financial Application**

A simple and intuitive finance application for novice investors linking all investment accounts. Users can monitor and research new opportunities in an interface that caters to inexperienced investors, without the large amount of unwanted financial information that other applications offer. A low-cost alternative to current market options.

### **PETQUEST: Pet-Adoption Matching Application**

A mobile app that helps users find pets in their area from adoption shelters, with filters to enable finding optimal pets that best suit the user’s life profile. Users answer questions about their pet needs and return a search query of pet profiles in the area. These profiles will be created by local adoption agencies seeking to find prospective families for their pets. PETQUEST provides a more streamlined experience over other commonly known pet adoption online services.

### **Operational Flight Scheduling for Moody AFB**

This team was tasked with creating a flight scheduling platform to improve what is now being used at Moody Air Force Base. This web-based flight scheduling application allows users to log on and add, edit or delete flights. It also generates a flight schedule for the week, which can be customized to create an individual pilot’s flight schedule.

### **“LegacyNet” Cemetery Drone Image Analysis**

Automates a tedious process of mapping headstones for an online resource provided by the National Cemetery Administration Veterans Legacy Program. LegacyNet uses machine learning to analyze photographs of cemetery layouts taken by drones. To map the cemetery, the sponsor needs to label each headstone with its coordinate location and its biographical information. LegacyNet automates the process of noting every headstone’s location. Previously the client performed this process by driving to the cemetery and noting the location of every headstone into a computer by hand.

### **Primary Source Database Analytical Tool for History Revealed, Inc.**

The “Shopping Stories” database is a cost-effective, cloud-based web application database tool to help researchers discover the hidden stories of people living in 18th century Virginia. Uses the powerful Neo4j graph database platform, which offers a robust suite of visualization tools. Hosted on Amazon web Services and open to users who can create an account and query the database.

### **Mobile Event Platform for Orlando Math Circle**

A mobile website to help OMC better coordinate events and create an inclusive community of students engaged in mathematics. This website is an open-source solution that can be maintained and expanded. OMC staff can create events, projects, set event fees, enforce attendance, manage volunteering, and notify users of upcoming events through email notifications. Parents can register their children, and users can learn about new projects and sponsorship opportunities. *(continued)*

## *Computer Science continued*

### **Predicting Cyber Security Vulnerabilities Using Meta Data and Machine Learning**

An open-source, no-cost web application tool that automatically locates security vulnerabilities and exponentially reduces the amount of manpower required to address them. The method exclusively examines *attributes* about the code (meta-data) rather than the code itself. This meta-data analysis approach leverages the way humans write code – so it can be used universally regardless of the coding language being analyzed. This team trained a machine-learning model to draw a correlation between meta-data and the percentage likelihood that a vulnerability is present in a file. A user submits their repository link and this model will iterate through every individual file in the repository, producing a roadmap to vulnerability hotspots. Created as a first-ever proof-of-concept.

### **The John Cage Tribute**

A tribute to the late American composer, this software allows users to create their own John Cage-like compositions. Four to eight performers use a mobile application to record their surroundings. These separate recordings are then sent to a server, where they are modified using an audio processing algorithm. Afterwards, the individual recordings are combined into one composition, which can be viewed on a mobile and web application. This project is the first to attempt replicating John Cage's style of music.

### **RxSys: Improving Prescription Compliance**

A mobile application (iOS and Android) for patients that will be integrated with pharmacies to help patients achieve prescription adherence. The app provides medication and refill reminders, and incentives such as coupons for properly adhering to a medication schedule. Pharmacists can manage patients and their medications through the web portal which features anonymous analytics gathered from patient usage. Each patient will be able to see their own improvements in medication adherence over time.

### **“SuperVisor” Assisted Reality Tool for Boston Whaler**

A proof-of-concept application using AR to support this boat manufacturer's operations. Designed to assist supervisors in tracking defective parts while on the manufacturing floor by providing relevant defect data of parts for each work station they manage. Supervisors can remain hands-free and no longer need to leave the floor to go to their desktop computer to get the same information. Assists in decision-making while managing a workstation, and streamlines operations. Helps labor costs and time costs from manufacturing delays. A second team of students that worked on this project is listed under Industrial Engineering and Management Systems summaries.

### **Athlete Technique Analysis: Sporsight Android Mobile Application**

Helps golfers enhance their golf swing techniques. Users record themselves, then, with machine learning algorithms, the software runs an analysis on the swing, then provides feedback such as pose estimations, trajectory visualization, statistical information, side by side athlete comparisons. This app also pinpoints the seven key frames of a user's golf swing. The application also allows users to annotate and record their feedback onto the video that can be shared to others such as their coaches and vice versa.

### **Sherlock 2.0**

This web-based tool helps in understanding why people make the choices they make. Can be applied in numerous settings, including video games. Sherlock 2.0 collects biometric data, displays it in an intuitive user interface, and analyzes in real time. Researchers can observe human reactions to audio-visual stimuli: heart rate, skin conductivity, facial expressions, etc. A machine learning algorithm derives various analytics, helping researchers understand emotional responses to stimuli and predict user response.

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## *Computer Science continued*

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### **Concurrent Blockchain Correctness**

Blockchain technologies are dynamic ledgers that record and validate events such as transactions, and are the foundation of cryptocurrencies. This project provides proof-of-concept implementation of a concurrency protocol for smart contract execution in a simulation of the Hyperledger Fabric blockchain. Checked with a Correctness Tool developed by computer science faculty, the simulation is calibrated to model the execution path and timing of Hyperledger Fabric. Transactions are queued in the simulator and executed correctly. The Correction Tool validates in real-time. Taking advantage of multi-threading to speed up smart contract execution is an underused process that could provide significant benefits to blockchain efficiency and throughput.

### **PegasOS: A 64-bit Raspberry Pi 4 OS**

A new open-source operating system for the Raspberry Pi 4. Its primary focus is for 64-bit support, but can also be compiled into a 32-bit kernel image. This project serves research and learning, but also is a functioning operating system. Provides an avenue to anyone with an interest in getting their own projects running on Raspberry Pi. It also allows anyone interested in operating systems to have a basic platform that can be extended and modified. Being a brand new kernel that is not Linux-based, PegasOS offers an alternate choice to existing Raspberry Pi operating systems.

### **Brain Beats: Making Music with Your Brain and AI**

A free music creation software suite that allows everyday people to create music using their own or others' brain waves, and then arranges the sounds into complete songs. Uses artificial intelligence with a simple user interface. Designed with simplicity and non-musicians in mind.

*(continued)*

## *Computer Science continued*

### **Endless Learner (ELLE) Virtual Reality Learning Games**

Provides an innovative way to learn a new language with a fun and educational tool. Created for a UCF language professor and intended for expansion into other language classes. The sponsor performs quantitative and qualitative research on the relationship between engagement and learning. To aid in this research, this project records different gameplay metadata, such as # of correct questions and total gameplay time. Unlike other VR language learning systems, this project allows for customization via website input. Language professors can create customized modules. Students can create an account on the ELLE website. ELLE tracks users' information which enables immediate feedback. The same data can be used by the professors to understand which platforms are most effective.

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## Fall 2020 Senior Design Project Summaries

# Electrical and Computer Engineering

### **“Pet Connect” Remotely Controlled Automatic Pet Door System**

Pet owners can let their pets outside from anywhere with this automatic pet door system. It easily installs to an existing sliding glass door and opens the door remotely via a mobile app. Sensors detect the pet approaching and sends a notification to the user’s mobile device. A camera allows users to see and verify their pet. Users can then open the door remotely via their mobile device. No permanent alterations to the door is necessary.

### **Polyphonic Analog-to-MIDI Converter for Musical Applications**

A device that gives acoustic and analog electrical instruments the ability to send messages to a digital audio work station just like a digital instrument. The Polyphonic Analog-to-MIDI Converter for Musical Applications accepts an analog signal from either a ¼” TS or XLR3 input and converts it to a MIDI signal of up to six voices. Designed to be used in studios or live performance settings. Other products that convert analog music signals into a digital MIDI stream are typically single-voiced; this project allows for six “voices” simultaneously, as in an acoustic guitar.

### **The Object Detection Drone**

Detects and recognizes objects using computer vision technology from an aerial viewpoint. The camera on an aerial drone relays the data back to the pilot and an application counts and shows detected objects. This project offers a lower-cost alternative to current products such as drones with thermal cameras. Other uses could include assisting event management or crowd management.

### **C.A.N.E. (Computerized Assistive Near Eyesight)**

Hands-free navigation for visually-impaired people. This project detects objects from a distance using a combination of computer vision, optical sensing and ultrasonic sensing. Once these objects are detected, the user will be alerted via vibration feedback to wristbands and audio feedback for more difficult obstructions. This project gives users much more information about their surroundings than what a cane provide, and helps navigate difficult obstacles such as staircases and doorways.

### **LookSee**

A small business autonomous surveillance security robot.

### **Automated Rescue Vehicle**

A lightweight, portable remote-controlled boat that serves as another set of eyes to autonomously aid in search-and-rescue efforts in large bodies of water. The boat uses automated navigation and a camera system with object detection and image processing capabilities. It can move about and scan the open water autonomously while maintaining the option for operator intervention. It sends a refreshing GPS location as it navigates, ensuring accurate location is sent despite weather changes or wave movements. The ARV’s depth sensor informs rescue teams of risk factors and what equipment they may need.

### **Project: Heat Emitting Automatic Temperature Square**

This team set out to rethink snow and ice removal in colder climates to reduce danger to pedestrians and drivers. The design uses a temperature sensor, a humidity sensor, heating element and LEDs. Data is sent to and processed by an Atmega 328P. If the data represents snow and ice conditions, the Atmega will turn on a relay to power on a heating system to melt the snow and ice. When the temperature reaches 50 degrees (F), the Atmega turns off the relay and heating element. Uses a WIFI module to communicate to a phone app. The project is demonstrated on a one-foot wood square topped with a paver to represent a sidewalk or driveway.

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## *Electrical and Computer Engineering continued*

### **S.M.A.C -Smart Mail Automated Center**

This team has designed a system for accepting deliveries in a secure box at a residence: a lockbox with multiple unlocking options, and a mobile application to protect items from theft. A lower-cost solution for consumers, ensuring their deliveries are safe when they're not home.

### **Farming Assistant & Solar Tracker (F.A.S.T)**

Addressing the issue of crop loss due to climate change, F.A.S.T. provides an easy and intuitive way to monitor fields and react to vital data accordingly. The design uses a plethora of sensors that provide measurements such as wind speed, air temperature, soil moisture, and several others. Can assist anyone who needs climate data specific to nuanced regions (farmers, grounds keepers, climate scientists, etc). System is lightweight, equipped with solar tracking ability, collects widespread data from multiple in sync devices, and provides data access via Bluetooth.

### **Curbside Automated Trashcan (CAT)**

A solar-powered, Wi-Fi enabled motorized garbage bin to automate and schedule curbside placement. This robot responds to commands on a mobile application and drives itself to the curbside. The CAT follows a line that outlines the path from the start point to the end point. After the trash has been emptied from the CAT, the user can command for it to return home to be refilled. An Internet of Things product that can be controlled from anywhere. No similar product exists on the market. Could also be used in commercial settings. This project aims to eliminate physical demands, incorporate ease, and facilitate efficiency.

### **“Super Brute” RV Jack for Husky Towing Products**

Provides a user-friendly interface to control an automated lifting jack for recreational vehicles. Users will connect to the system with a mobile application and control the extending and retracting of the lift. Targeted for RV owners, but can be used for other large vehicles. While many motor controlled RV jacks exist, Super Brute uses a mobile phone as the remote control. Includes additional safety features such as the ability control external LEDs.

### **Distributed Sound Detection and Location System**

This project provides surveillance of an area for loud sounds, including gunshots or thunder, to inform people of the originating location immediately. The system involves surrounding a defined area with sound sensors. By measuring the relative time it takes for the sound to reach each sensor it can calculate the location of the sound's origin, which is then displayed on a web app. Each sensor in the system is designed to be low-cost, small, and weather resistant. Could be used to automatically provide alerts on college campus regarding the detection and location of gun shots; and if properly scaled it could also be used to monitor the location of lightning strikes to help determine possible locations of forest fires.

### **Automated Home Hydroponics**

A general-purpose automated home hydroponics system that monitors growing conditions for optimal plant growth with minimal user intervention. The system is geared towards the average plant enthusiast who wants to grow vegetables, flowers, or anything that can fit the design. An app assists the user in monitoring plants with additional features to update the system. A cost-effective, unique solution that can hold up to 54 plants.

### **Backpack E-Skate**

An electronic skateboard with the ability to fold in half lengthwise for portability, either inside a backpack or attached to the outside. The reduced form factor from foldability solves a storage problem when students enter a classroom, bypassing the need to pile them up together. Equipped with safety features such as LEDs and various sensors. Cheaper electronic skateboards on the market do not have as many features as the Backpack E-Skate.

## Industrial Engineering and Management Systems

### **Turtle Tracking Database Phase II**

The ability to track, store, and export data easily with 40+ years of sea turtle tracking records enables better understanding of the impacts of Florida's ecological changes. A continuation of previous students' work to create a Turtle Tracking Database for UCF's Marine Turtle Research Group, this new website is a more user-friendly method for users to input their collected data. It provides easier methods for searching and storing data, and mitigates input errors by notifying the user with suspected errors. The team fine-tuned the website, checking for errors through a client-feedback-based Failure Mode Effect and Analysis (FMEA) that combines system importance, customer importance, and ease of implementation into a ranked order. CS students wrote or appended existing source code, enabling the client to migrate to the new site that is more user-friendly, more efficient, and easier to operate.

### **Strategic Spares Inventory Analytics and Process Improvement for Siemens Energy**

This team set out to improve inventory management of strategic spares and non-stock parts inventory across Siemens Energy so that all groups within the company follow standardized procedures and process flows. This team also worked to minimize inventory holding costs while ensuring enough inventory is available to meet demand and meet sales goals. The proposed process forecasts demand for replacement parts based on historic data. Holding costs are minimized, revenue is maximized.

### **Artificial Intelligence in the Colombian Judicial System**

This team proposed an AI-based system to increase operational efficiency in the law firm, Conde Abogados, to ultimately help the firm save time and money. The program uses artificial intelligence – widely used in judicial systems around the world – to aid the law firm in choosing which cases to accept by predicting the outcomes of cases and identifying new patterns. The final project will guide the client in successfully planning, applying and using the team's research.

### **“SuperVisor” Assisted Reality Tool for Boston Whaler**

A proof-of-concept application using AR to support this boat manufacturer's operations. Designed to assist supervisors in tracking defective parts while on the manufacturing floor by providing relevant defect data of parts for each work station they manage. Supervisors can remain hands-free and no longer need to leave the floor to go to their desktop computer to get the same information. Assists in decision-making while managing a workstation, and streamlines operations. Helps labor costs and time costs from manufacturing delays. A second team of students that worked on this project is listed under Computer Science summaries.

### **Innovating the “Last Mile”: Market and Financial Research for Routing and Logistics Software**

This team has designed a method to improve delivery operations in the “last mile” – the final route a delivery takes before reaching its destination. Current issues include lack of communication between dispatchers and delivery staff, manual routing, and more. This team analyzed customer “pain point” interviews around North America and compared the findings with industry leaders; and developed a competitive, optimized hybrid-approach solution that helps sponsor keep up with growing delivery demand while reducing distribution costs. Service levels are adjustable according to size of the business.

### **Experiential Reality Interoperability Research: Investigation, Analysis, and Findings**

This team conducted a Systematic Literature Review of the capabilities of eXperiential Reality (XR) Interoperability for their client Naval Air Command Systems. XR is rapidly evolving and holds great potential. The team used 6 Sigma strategies to extrapolate, analyze and develop recommendations for the client. The team used a range of different databases to search for developments in AR/VR technology and use parameters, and has provided a cohesive review in five relevant themes: Analytics, Education, Experimentation, Testing/Evaluation and Training, targeting different applications of XR technology.

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## *Industrial Engineering and Management Systems continued*

### **Torito Brands Facility-Designing Knights**

This team proposed an optimized design of a new 6,500 square-foot facility for Torito Brands, a fast growing dog chew company. The layout of the fully optimized facility will be efficient to improve processing and shipping, and will incorporate key quality ideas. The team has incorporated different industrial engineering facilities principles such as activity relationships, space relationships, and material flow and handling.

### **Production Optimization for Toritos Brands**

This team analyzed the supply chain and production system of the fast-growing company Nature Gnaws, which makes 100% natural dog chews, and identified areas for improvement. The company is experiencing problems keeping up with increased demand and projects tripling their total sales in years to come. After conducting time studies and observing current production processes, the team has proposed scalable production practices that can be implemented to handle expected growth.

### **An Analysis of Testing Bottlenecks and On-going Data Collection for Contec Americas Inc.**

This project focused on collecting and providing accurate routing data for Contec Americas, Inc.'s products during testing, with distinctions made between machine time and labor time, to optimize the testing process. Due to the pandemic, the team conducted time studies virtually by watching videos of the testing process. The team analyzed the data and proposed solutions aimed at increasing throughput in the testing process. Demand for the company's products has increased; therefore faster production times and streamlined processes are needed. The proposed solutions can be applied to future product lines.

### **Process Improvement for Advanced Vascular Solutions**

This team worked to produce short-term and long-term solutions for AVS, a specialized medical practice that provides venous, arterial, and wound care. The team analyzed data including scheduled appointment times, arrival and departure times, and procedure type. They conducted simulations using queuing theory to estimate the wait time of each patient. Using Lean Six Sigma methodology, they eliminated non-value-added factors to reduce patients' wait and service times. The proposed solution ultimately will improve scheduling and patient satisfaction, all while ensuring patient health and safety, and at the same time maximizing AVS's revenue. The solutions could be applied in other small medical practices.

### **Production Schedule of the First Executive Supersonic Jet**

This team worked to optimize the production schedule for Melbourne, Florida-based Aerion Supersonic in support of the company's efforts to produce the supersonic "AS2" aircraft. Currently, the assembly of the wings do not match the rate of assembly with the remainder of the aircraft. The holding time between the assemblies causes waste of facility space and inconsistent production time. This project aims to minimize the holding time between the assemblies to achieve improved flow. The revised production schedule allows for lower hold times between the three assembly processes. The process of this revision can apply to other aircraft production lines and will allow for a smoother assembly process and a more flexible demand over the next 6 years.

### **Steelcase Ology Desk Cost Reduction**

This team sought to carefully examine the design of a height-adjustable desk sold by Steelcase in an effort to find areas where cost can be reduced, all while keeping the changes invisible to the customer and maintaining the same level of quality. The team achieved this goal through cost analysis and Quality Function Deployment, to grant Steelcase the ability to lower their material cost and make a greater profit from one of their most high end desk designs.

## Mechanical and Aerospace Engineering

### **Storm Drain Inspection Robot for UCF Utilities and Energy Services Department – Black Team**

Small and durable, this robotic system inspects for cracks and blockages inside UCF's vast network of storm drains. Includes multiple sensors, a camera, lights and the ability to add additional modules/tools such as removing items lodged in drains or a rotary tool to cut away corrosive buildups. The robot's onboard power and control system means it can return to its starting position in case of signal disruptions to/from the operator. Made with off-the-shelf parts, and costs a mere fraction of similar products. Open-sourced allows future expansion such as new sensors and modules increasing robot's lifespan. Inspections from third-party vendors can cost around \$15,000 per visit. Durable and user-friendly.

### **Underwater Remotely Operated Vehicle - Green Team**

Teams were challenged to create aquatic ROVs and compete in an obstacle course of hoops and poles to test maneuverability, speed, acceleration, and reliability within a time limit. The project demonstrates understanding of fluid mechanics, computer-aided design, finite element analysis and controls. The Green Team's design is a semi-autonomous system which will allow the vehicle to be tethered or untethered. It features a camera with live footage to give operator a first-person view.

### **Underwater Remotely Operated Vehicle - Red Team**

Teams were challenged to create aquatic ROVs and compete in an obstacle course of hoops and poles to test maneuverability, speed, acceleration, and reliability within a time limit. The project demonstrates understanding of fluid mechanics, computer-aided design, finite element analysis and controls. The Red Team's design is simple and low-cost, using readily available materials.

### **Coca-Cola Reverse Osmosis Water Filtration**

This team was challenged to improve the water filtration system and promote water conservation at a beverage production plant where current output has surpassed its RO filtration system capabilities. The proposed design introduces a two-stage twin RO system coupled with a unique valve manifold design. An additional RO array of equal capacity as the original system would attach to the original array and be responsible for filtering its reject water, significantly increasing water recovery efficiency during normal operation. Simply put, the two sides of the system can operate in conjunction and complement each other, or they can operate independently, offering a high level of operational flexibility.

### **Robotic Generator Inspection for Mitsubishi**

A robot that can inspect generators of various sizes, fit into a small entry gap, and conduct the full array of tests on any generator. Miniaturized design is compact enough to enter a much smaller entry gap; yet it overcomes variations in size to correctly conduct the testing for each part in the range of generators. Design has the testing capacity as a robot that is four times the size. Designed to overcome the tradeoffs between cost, size, and features.

### **Aircraft Active Structural Health Monitoring System - Green Team**

Aircraft operate in dynamic conditions such as turbulence and variable loading which could lead to deadly structural failures. Active structural health monitoring (ASHM) measures stress and strain through the body of an aircraft to predict or locate structural damage, and instantaneously reports it to the user, reducing the operational costs and increasing aircraft lifespan. This sensor system installed within the wing of a UAV measures and transmits the effects of these variable loads via strain values. The UAV releases payloads during operation to test the response of the sensing system to external loads. This project tests and proves the usability of an ASHM system, and provides the foundation for future improvements.

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## *Mechanical and Aerospace Engineering continued*

### **Aircraft Active Structural Health Monitoring System – Red Team**

Aircraft operate in dynamic conditions such as turbulence and variable loading which could lead to deadly structural failures. Active structural health monitoring (SHM) measures stress and strain through the body of an aircraft to predict or locate structural damage, and instantaneously reports it to the user, reducing the operational costs and increasing aircraft lifespan. In this project, strain gauges are applied directly to the structure and measure selected parameters during flight. Data gathered is then filtered through a Data Acquisition unit and is analyzed by ground support engineers. Any affected or at risk areas can then be repaired as needed. Current technology is not yet widely available or desirable due to weight constraints. By doing strategic analysis on the aircraft structure to determine high risk locations, weight can be minimized and the system incorporated.

### **Gasket Splicing Automation for Total Refrigeration Gaskets**

This project improves upon previous attempts to create an automated gasket splicing machine. Currently TRG achieves its '90° corner splice' (which creates a perfect seal between a refrigerator and its door) with manually operated machines. An automated machine is a pneumatic actuation system that assumes control of most main components, such as the heating block and fixture movement, to speed up the splicing process. The solutions proposed by this team are to improve the function of the automated machine by integrating the improved components seamlessly, therefore increasing operation reliability. The updated design will allow the machine to be more easily operable while maintaining or improving consistency of the gasket. Key components will either be kept, optimized, repurposed, or completely redesigned as necessary to meet this result.

### **Desktop Wind Tunnel Instrumentation**

UCF's Measurements Laboratory has wind tunnel experiments that further students' understanding of key concepts in engineering (fluid mechanics, measurements, data analysis, etc.) by modelling objects in flow. However, these experiments are heavily limited in the quality of data and the time it takes to collect the data. This project improves these aspects with modifications to the current wind tunnels: AirTech Scout 2.0, with three different experiments: preliminary test chamber analysis, study of flow over a cylindrical rod, and study of flow over a rectangular rod. This improvement is done at a low cost and provides a more comprehensive understanding of wind tunnels. This project provides new and improved mounting techniques and simpler test subjects.

### **Design and Installation of a Particle Image Velocimetry (PIV) Experiment for Undergraduate Laboratories**

PIV is commonly used diagnostic technology to analyze flow over various surfaces to better understand velocity and vorticity profiles. This PIV system to be implemented at UCF into undergraduate laboratory-based courses will be water-based with a built-in analyzation process to assist students in learning about PIV. Designed for undergraduate-level experiments so students can begin working with a PIV system early in their undergraduate career.

### **Solar Desalination Using Solar Radiation and a Vacuum Boiler – Black Team**

To enable access to clean water in times of disaster. The system is composed of multiple subsystems of tubing, a filter, a solar water heater, a vacuum chamber, and a condenser. At the intake, water from a local source (groundwater or seawater) enters a filter and a solar water heater. The water exits the heater and enters a vacuum chamber which will boil the water and produce steam. The resulting condensation is collected, ready for human consumption. Designed to be easily disassembled for potential relocation if needed, a feature most systems do not have. Current desalination systems also cost a significant amount to yield the desired water quality. This system only generates electricity via solar radiation and then relies on heat transfer and fluid mechanics.

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## *Mechanical and Aerospace Engineering continued*

### **Serpentine Solar Desalination System – Blue Team**

A system that converts saltwater into drinking water using solar energy. This design can provide enough daily drinking water for 4 to 5 people. Saltwater is stored in a tank at the beginning of the system and its flow is controlled by a spigot. The saltwater flows through pipes into a compound parabolic concentrator mounted with a serpentine concentric tube setup. To remove salt from saline water, the solar energy absorbed by the compound parabolic concentrator is converted into thermal energy. The thermal energy causes the water to evaporate while the salt remains within the inner tubes. Water then condenses and flows into drinking water collection containers. This system applies a serpentine tube configuration to increase the time the water spends being heated throughout the system and, in turn, function more efficiently. This low-cost system does not require an internal power source or complex components.

### **Solar Desalination Project - Gold Team**

This solar still is affordable and simple enough for the average user to assemble, maintain and operate, yet efficient enough to yield enough clean drinking water to support four people. The design is a slope-style solar still that has been modified to use stepped basins. The basins function as the solar collectors and work to effectively transfer sunlight into thermal energy. The basins transfer their thermal energy into the contained water, increasing its temperature which induces a higher rate of evaporation. The still was designed to maximize the ratio of water evaporated to the volume of air in the still, so that the contained air becomes heavily saturated and condenses at a high rate. To further increase the condensation rate, a condenser cooling device was implemented.

### **Solar Desalination Project – Green Team**

A simple, efficient desalination system that provides daily water for one individual. To keep the solution accessible without electrical input, the team has chosen a solar-driven desalination system. After conducting research and analyzing successful systems on the market, the researchers decided to design an optimized solar still with passive wicking technology in order to distill seawater at more than twice the yield rate of conventional systems.

### **UCF Formula Society of Automotive Engineers Design Team**

The FSAE race car overheats when operated in hot air temperatures (80° F or higher). Overheating can result in engine failure and repair costs. This project is a new cooling system to efficiently and effectively cool the car using a custom aluminum counter-flow heat exchanger with a custom carbon fiber air duct system. The more efficient counter-flow heat exchanger was chosen (vs a parallel-flow heat exchanger) because cold and hot fluids flow against each other in opposite directions which distributes the heat more evenly across the system and allows for maximum performance. The new cooling system design has a minimal effect on the aerodynamics of the vehicle. A custom heat exchanger with an air duct system (vs a dual side-pod design) was chosen to allow the max amount of air flow through the system while having the least amount of drag on the race car.

### **Distributed Electric Propulsion Aircraft Design- Blue Team**

A revolutionary method of aircraft propulsion that's quieter, cleaner, more efficient, and more sustainable with zero-emissions battery propulsion – an alternative to fuel-powered jets. This project uses one lithium polymer battery to power eight electric motors, four on each side of the aircraft, with each propeller rotating at high speeds. This design allows the aircraft to take off and land over shorter distances and at lower speeds, which results in better flight conditions and access to remote areas. Higher energy efficiency results in longer flight times. The additional motors also allow for more thrust generation which enhances the aircraft's ability to overcome air-resistance drag. In the long-term, a complete shift towards fully-electric flight is heavily anticipated, and research is ongoing to better understand methods to arrive at large and long-haul commercial planes. Applications for DEP aircraft are limitless.

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## *Mechanical and Aerospace Engineering continued*

### **Distributed Electric Propulsion Aircraft Design- Gold Team**

A revolutionary method of aircraft propulsion that's quieter, cleaner, more efficient, and more sustainable with zero-emissions battery propulsion – an alternative to fuel-powered jets. This project uses one lithium polymer battery to power eight electric motors, four on each side of the aircraft, with each propeller rotating at high speeds. This design allows the aircraft to take off and land over shorter distances and at lower speeds, which results in better flight conditions and access to remote areas. Higher energy efficiency results in longer flight times. The additional motors also allow for more thrust generation which enhances the aircraft's ability to overcome air-resistance drag. In the long-term, a complete shift towards fully-electric flight is heavily anticipated, and research is ongoing to better understand methods to arrive at large and long-haul commercial planes. Applications for DEP aircraft are limitless.

### **Micro Unmanned Aerial Vehicle - Black Team**

A small electric powered aircraft that can carry a payload of 32 fluid ounces, to compete against other teams to perform the maximum number of laps around a track.. It uses a propeller that pushes turbulent air behind the body of the aircraft (vs pulling the aircraft from the front) thus leaving an uninterrupted airflow across the aircraft surface. An aircraft such as this can be used in a wide array of applications, from surveillance and defense to education. The design of this aircraft is based on a lower budget so that it would be more accessible for a variety of implementations. In addition, it provides students with valuable knowledge of aerodynamics, structures, electronics, and manufacturing.

### **Micro-Unmanned Aerial Vehicle – Blue Team**

A small electric powered aircraft that can carry a payload of 32 fluid ounces, to compete against other teams to perform the maximum number of laps around a track. Since the payload is liquid, the plane will be highly unstable. Several methods were explored to allow the aircraft to stay in control during flight. Use of an electric motor system was required. This one aspect differentiates this micro-UAV project from UAVs now available. A possible application for this project would be a platform for instrument testing, as the goal of the project is to keep the aircraft as stable as possible.

### **Micro Unmanned Aerial Vehicle - Gold Team**

A small electric powered aircraft that can carry a payload of 32 fluid ounces, to compete against other teams to perform the maximum number of laps around a track, capable of performing standard flight procedures (i.e take off, maintaining flight, and landing) while carrying the specified payload. The project required electric propulsion with at least one pusher-configuration propeller. This team strived to create a fixed-wing UAV with high durability, cost efficiency, and an ease of manufacturing, and chose a joined-wing PrandtlPlane configuration not commonly considered in past similar projects. This configuration uses two wings, one at the front and one at the rear of the aircraft, rather than a traditional wing and tail, resulting in an aircraft with lower induced drag and greater structural stiffness than other fixed-wing UAVs.

### **Accessible Wheelchair Transfer System**

An innovative aftermarket device to add to wheelchairs to enable paraplegic users with upper body mobility to independently transfer in and out of their wheelchair, to and from surfaces of different heights. A sliding track mechanism extends from the wheelchair, allowing user to maneuver away from the obstacles of the wheelchair frame. Simply press a button on a handheld controller to lower the linear actuator foot, then move the wheelchair backwards causing the trackway to extend out in front of the wheelchair. Pull on handles to get to the front of the extended-out trackway. The user can lift or lower the entire trackway. At the desired height, a slide board resting underneath the sliding chair is pulled out enabling the user to transfer themselves from the slide board onto the new surface. Made with simple materials that will dramatically reduce the cost of assembly.

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## *Mechanical and Aerospace Engineering continued*

### **Partial Hand and Finger Prosthetics**

Intended for partial hand amputees, this prosthetic device is designed to allow configurable grip patterns and intuitive control measures to lessen the learning curve for externally powered partial hand prosthetics. This device will provide intuitive control through the implementation of various sensors on the prosthesis. The sensors will allow the user to provide an input into the device, knowing that the result will be a desired prehension or gripping pattern. Existing partial hand prosthetics rely heavily on EMG controlled input which can take months for amputees to master and come at a high cost. This low-cost device will accomplish more than a body-powered device without the grueling learning curve and issues that come along with externally powered myoelectric prosthetics.

### **“RE-vent”: Low-Cost Ventilator Design - Blue Team**

To address global shortage of ventilators by being cheap, fast and easy to manufacture while providing the same function as hospital mechanical ventilators. This project's driving force for ventilation is a piston that is motor controlled by an Arduino control unit. A series of electronically controlled valves control the flow of gas into and out of the piston compression chamber. The gas then moves into a separate chamber with heated water to humidify the gas before delivery to the patient. A screen interface allows for the user to input a desired tidal volume and respiratory rate to the patient. This design includes a humidifier, variable tidal volume and respiratory rate, as well as a pressure triggered mode of respiration. Lightweight, portable, and includes a backup power supply.

### **Low Cost-Respirator/Ventilator Design - Red Team**

This ventilator aims to provide mechanical respiration for patients in low-income communities at a fraction of the cost of standard-practice ventilators through the use of a readily available and disposable resuscitator mask in conjunction with a linear actuator for compression. It provides controls in tidal volume, breaths per minute and inhale-to-exhale ratio; and, unlike other low budget ventilators available, it also provides PEEP valve control, and pulse and oxygenation readings to further improve assessment of the patient.

### **Self-Stabilized Bicycle**

A bicycle that automatically stays upright without the need of a rider or forward movement. This system is a reaction wheel that imparts a torque to counter the force of gravity that makes the bike want to fall to the side. The system works by having an Inertial Measurement Unit sensor collect information about the tilt angle of the bike. It works in a similar way to a smartphone changing the screen orientation when held in portrait or landscape. This tilt information is fed into a control algorithm that tells the motor of the reaction wheel to move a certain speed and in a certain direction. Similar control systems exist for commercial products such as Segway® and Hoverboards but not for a bicycle form factor. Could aid in learning to ride a bike by providing some assistance when balancing, or could be reconfigured into an autonomous balancing robot to provide thrilling camera aspects for bicycle races such as the Tour de France or motorsports.

### **Low-Cost Multi-Patient Ventilator - Green Team**

A low-cost alternative to the typical hospital single-use ventilator. This multi-patient system uses a bag valve mask system. A bellow pump will be used in place of the bag to uniformly compress the bellow and provide oxygen to the patient. A peristaltic pump will act as an inlet pump along with one-way valves to force compressed medical gases upstream through the mechanical components of the ventilator. This design concept uses machinery that is typically manually operated to create a multi-use system at a cost similar to single-use ventilators. This project focuses on usage in low-resource areas by incorporating aspects of reusability, easy sterilization, and lower cost. Simple to operate, easy to disinfect and reuse, and space effective.

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## *Mechanical and Aerospace Engineering continued*

### **Drone Racing - Black Team**

A cost-effective X-Class Drone that balances power/speed and structural support within a realistic budget. The drone's dimension requirement of 800mm-1000mm must acquire a top speed of 100 mph. Additional project goals included setting up a racetrack for both participating teams and a point system for scoring to evaluate each team's drone performance. Based on the racetrack and point system, additional implementation of a release mechanism for each drone was put in place, to release golf balls to increase the score of each drone. The main challenge was to maximize performance while keeping and carefully placing the funds given in contrast to purchasing an already built drone, and making the release mechanism that is not offered in said drones.

### **Drone Racing – Gold Team**

This team designed, manufactured and tested a racing drone built within required specifications. A race style drone that is larger than standard drones, between 0.5m to 1m, and is capable of carrying/offloading cargo which in this case will be golf balls, with ability to tightly maneuver around obstacles.

### **Computer Numerical Control (CNC) Router – Green Team**

Intended to add another tool in the UCF engineering students' toolbox for manufacturing projects. This team designed and built a professional machine that will reduce the workload in the UCF Manufacturing Lab and expand Senior Design students' machining capabilities. A CNC Router is similar to the laser cutter found in UCF's Innovation Lab. It cuts mechanically using high-speed, rotating bits; however, it can process more types of materials and can cut materials that are much thicker than ones allowed in the laser cutter. The router uses a computer controlled cutting head, which ensures precision machining operations to produce high quality parts. The cutting head is driven by motors that translate a total of three axes of movement in a precise and controlled fashion. The router is able to machine a plethora of materials, including soft metals, woods, plastics, foam, composites, and precision components, such as printed circuit boards. CNC routers are abundant in many industries. Having one at UCF gives students hands-on experience using one.

### **Computer Numerical Control (CNC) Router – Red Team**

Intended to add another tool in the UCF engineering students' toolbox for manufacturing projects. This team designed and built a professional machine that will reduce the workload in the UCF Manufacturing Lab and expand Senior Design students' machining capabilities. It gives UCF the ability to cut a large footprint of material that was unavailable in the past as well as providing a variable z-axis dimension. It also frees up space for existing machines in the Innovation Lab and Manufacturing Lab to allow more availability to students. In addition to its range of material and footprint, this machine is also capable of cutting large precision work.

### **Golf-Ball Retrieval: Semi-Autonomous Ground Vehicle – Blue Team**

To retrieve golf balls. This vehicle will compete in a competition against other Senior Design teams

### **Golf-Ball Retrieval: Semi-Autonomous Ground Vehicle – Gold Team**

Operates indoors and outdoors, and can detect and identify objects intelligently. This design weighs less for easier transport and can toggle between autonomy and manual override. Once it's placed in a field, the camera scans for intended objects (golf balls). Once it detects its object, pixel information is sent to the onboard logic board, which runs the autonomous function that propels the motors at a set speed, constantly updating on the new target pixel locations. As a golf ball passes underneath the vehicle, it gets wedged between a set of rollers that keeps the ball locked in. As the vehicle continues to move, the rollers spin around a shaft, taking the golf ball with it off the ground and rotating it until it hits a set of forks at the top of the vehicle. The forks dislodge the golf ball, which falls into a storage container. When the vehicle reaches load capacity, the target recognition system looks for its drop off marker and navigates to it, then a servo motor is actuated to move a gate, dispensing the golf balls on a small incline. At any time, the vehicle can be manually overridden and controlled with a remote RC controller.

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## *Mechanical and Aerospace Engineering continued*

### **Golf-Ball Retrieval: Semi-Autonomous Ground Vehicle “ Robo Gator” - Green Team**

This system uses sensors and cameras to track its location and scan its surroundings. The onboard pick-up mechanism collects golf balls while the vehicle moves and simultaneously stores them in a container to later be deposited when the vehicle has arrived at the designated drop-off location. A servo-driven sliding door on the side of the vehicle will open, allowing the balls to exit using the potential energy of the ramped containment unit. All actions are controlled through a microcomputer, directing the vehicle as to where and when it should move, as well as what tasks to carry out in its current location. Provides a lower-cost alternative to similar ball-retrieving robots that cost around \$9,500.

### **Golf-Ball Retrieval: Semi-Autonomous Ground Vehicle – Red Team**

An affordable way to speed up golf-ball collection with little to no human input. Color and object detection algorithms are built into the PixyCam that detect the golf balls. Then, an automated process to collect the golf balls is initiated through an implemented code. The vehicle's receiver receives the incoming signal from the transmitter inside the handheld remote control. Manual control allows the user to operate all aspects of the vehicle's movement, including the roller mechanism and storage container flap. The system runs on a rechargeable battery and allows itself to operate continuously throughout the day. This vehicle cuts the downtime between each game, lowers labor costs to maintain the fields, and decreases the risk of injury.

### **Projectile Launching System – Green Team**

This semi-autonomous system recognizes a target, aims and launches a projectile into or as close to a target as possible. Using computer vision algorithms, the system identifies target locations. The information is then used to calculate a target range and a suitable firing angle. Compressed air is released launching the ball in a parabolic trajectory towards the target. The concepts used in this project could have commercial and military applications, such as a low-cost short-range mortar launching system. Additionally, the accurate placement of projectiles downrange could be useful for the bulk dispersion of seeds in agriculture. This project employs autonomous operations to reduce human error.

### **Projectile Launching System – Red Team**

This system recognizes a target, aims and launches a projectile (golf ball) into or as close to a target as possible. The design entails a pneumatic launcher that will use computer vision to obtain location-specific information. It will then adjust the position of the launcher to aim at the target. With the use of miniature computers and solenoid valves, a golf ball will be launched directly at the target. The defense industry could use the autonomous target acquisition and aiming system and adapt it to their specific needs. In athletics, the system could assist in training athletes in certain sports. It can also be used in the classroom as a hands-on way to learn engineering core concepts.

### **Projectile Launching Mechanism – Blue Team**

A projectile launcher that can hit targets up to 100 yards away with accuracy and consistency, using compressed air to fire a golf ball to specified targets. With a mobile app and Bluetooth connection users tell the launcher where the target is. The launcher then aims and positions itself. Once in position the launcher will fill its tank to the calculated pressure. A button on the mobile app allows the user to manually fire the launcher.

### **“Aerodynamic Drag Reduction System” for UCF Knights Racing FSAE Team**

As objects travel through air, various aerodynamic forces act on them: some desirable, and some not. Cars and planes often have movable external surfaces or are shaped in such a way to minimize or maximize the effect of these forces. This team designed a system to minimize the undesirable forces acting on a racecar using movable control surfaces. The concept is used for aircraft taking off, cruising, and landing; and in automotive applications. This project demonstrates a simple way to achieve better efficiency, and a cost-effective method to reduce the effects of undesirable external forces.

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## *Mechanical and Aerospace Engineering continued*

### **Sustainable Packaging for Steelcase**

Steelcase seeks to adopt a circular model (reusable packaging) to its packaging and delivery structure to significantly reduce the number of new boxes entering the system. Currently, the boxes and internal safety constraints have a ranging value of 5 to 15 dollars per chair, throughout a multi-stage delivery network. The client's goal is to create a system within a budget of 20 dollars per reusable package. Each package must survive at least two cycles to ensure a return on investment; and pass Steelcase's environmental and vibration tests. The team chose a design that is readily manufacturable and fits into Steelcase's budget, after consulting with manufacturers and designers and prototype testing. An industrial engineering team also provided input on this project earlier this year.