# Vaughn College Journal of Engineering and Technology
# April 2018

## ACHIEVING IMPACT

**"The purpose of life is to contribute in some way to making things better."**
**Robert F. Kennedy**

**The Vaughn College Journal of Engineering and Technology** (VCJET) is published annually in preparation for the Technology Day Conference. It includes events and activities of the Department of Engineering and Technology, such as faculty professional development, student engagements, robotics competitions, UAV activities, poster competitions, conference presentations, and publication of the best student research papers.

Given the rapid pace of technological change, the Journal is intended to assist Vaughn engineering students in developing a mindset that recognizes lifelong learning as necessary in order to meet future professional challenges. The ultimate aim of the Journal is to engage and prepare students for the future in engineering research and innovation. Furthermore, this Journal research project strengthens student learning outcomes related to critical thinking, problem solving, communication, and teamwork. The enhancement of these learning outcomes through engineering and engineering technology programs not only provides students with an excellent education, but also helps them develop leadership and entrepreneurial skills.

A journal paper project must be developed and investigated in such a manner that it satisfies the learning objectives of engineering education. Some of the learning objectives emphasized in the development of a technical paper are:

1. Intention plan (Abstract): Developing a proposal that outlines the details of a project and its impact on local and global society
2. Application: Identifying the use and application of the project in global society
3. Methodology:  Providing a brief description of methods and solutions
4. Teamwork: Identifying team members and their responsibilities in the project's development
5. Modeling:  Providing a complete and precise drawing of the project
6. Analysis: Providing all necessary analysis and analytical tools used to satisfy the system's safety and computing requirements
7. Conclusion: Discussing the result(s) and the contribution of the project to local and global society
8. Reference:  Identifying research references
9. Presentation: Presenting the selected design paper in a Microsoft PowerPoint format to the industry advisory members, faculty, and other members in the audience during the Technology Day Conference

The Journal's topics include technical papers that are related to computational mechanics, solid mechanics, mechatronics, robotics, avionics, electronics, and other topics pertinent to the engineering and engineering technology fields.

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# Contents

4

**Research and Technical Papers**

6

### A Brief Review of Vaughn College's Ninth Annual Technology Day Conference,
### April 27, 2017

Vaughn students, faculty, alumni, and industry professionals convened in April 2017 for the College's Ninth Annual Industry Advisory Meeting and Technology Day Conference. Advisory Council members were given updates on recent developments in the Engineering and Technology Department such as progress reports on: the new Mechanical and Electrical Engineering programs, the new 3-D Prototyping Innovation Center and Machine Shop, Vaughn's Robotic team who ranked third place in the 2017 World Championship, Vaughn's UAV team who was selected by the American Helicopter Society (AHS) as a finalist alongside Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University to participate in the 5th annual Micro Air Vehicle (MAV) student challenge competition in Dallas Fort Worth Convention Center (May 8, 2017), and internships and other issues related to the development process of new stackable certificates in the advanced manufacturing program.

Vaughn College's Academic Vice President, Dr. Paul LaVergne, welcomed the guests and thanked our advisory members for their active participation in every aspect of our institution and he updated them on our recent Middle States site visit and accreditation. Dr. Hossein Rahemi, Chair of Engineering and Technology Department, thanked the advisory members for their continuous support and valuable feedback regarding all of the department's programs. He updated the advisory members on student and faculty professional development, the success of the Vaughn College Robotics Team as a 2016 Mexican International VEX U Robotics Champion as well as their accomplishment of ranking 3rd in the 2017 VEX U World Championship, the selection of Vaughn's UAV team as a finalists in both manual and autonomous categories by The American Helicopter Society (AHS) for the Annual Micro Air Vehicle (MAV) Student Challenge competition on May 8, 2017 in Dallas, Texas. Also, he informed advisory members about the new title III HIS-STEM grant "Developing Guided Articulated Completion Pathways in Leading Edge Aeronautics and Aviation Careers for Hispanic and Low-Income Students" funded at $5,999,754 by the Department of Education (2016-2021) for developing stackable certificate programs in Computer Aided Design & Additive Manufacturing, Composite Manufacturing & Repair, UAV Design & Application and a new Advanced Manufacturing concentration within the existing MET program.

The third speaker of the morning session conference was Mr. Oliver Scheel from US Didactic who talked about a new Pedagogy for Automation and Manufacturing, and he emphasized the importance of automation and robotics in advanced manufacturing curriculum. The fourth speaker was Prof. Manuel Jesus who has a strong background in computer-aided design and computer aided manufacturing. Prof. Jesus introduced the audience to four courses that can be used towards the development of a new Computer Aided Design and additive manufacturing certificate program. Finally, our fifth speaker, Dr. Budhoo, who has an extensive background in composite materials and laboratory testing, introduced his plan for a certificate program in composite design and manufacturing.

**Robotics, UAV, SWE, EWB, Automotive Clubs' presentation (11:00 pm to 12:00 pm)**

> Vaughn's UAV club presented their design process for both manual and autonomous quadcopters for participation in the 2017 American Helicopter Society Micro Air Vehicle Competition. Vaughn's UAV team was selected as one of the finalists along with Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University to participate in the 5th annual Micro Air Vehicle (MAV) student challenge competition in Dallas Fort Worth Convention Center on May 8, 2017. Both manual and autonomous drones for this competition are designed to perform vertical takeoff & landing (VTOL) with onboard flight-stabilization and camera. The drone's weight should be less than 500 grams and should have delivery, pickup, obstacle avoidance, and hover/landing capabilities. For both autonomous and manual, a drone with a package will take off from a base station, move around an obstacle and drop off the package on a pre-identified delivery station. The drone then would takeoff from the delivery station and land on the pickup station to pick up a 2nd package, and then finally fly back to the base station to land and deliver the package. This is a tough and challenging competition, and only the top teams who have supporting documentation and videos, who have proven that their drones can complete the tasks, were invited as finalists to compete in the Annual American Helicopter Society Micro Air Vehicle (MAV) competition.

➢ The Vaughn Robotics Club discussed several stages of their robotics design for VEX U Robotics regional, international, and world championship competitions. Invitation to the VEX U Robotics World championship will only be granted to a team that is a tournament champion or 'Excellence' award recipient of a regional competition. Vaughn's Robotics team were tournament champs of the College of Southern Maryland (CSM) regional Qualifier, recipients of the 'Excellence' award of Vaughn College Regional Robotics Competition, as well as the tournament champions of the Mexican VEX U Reeduca International robotics competition. The Vaughn Robotics Club discussed their innovative robotics design, in which one robot can be separated into two working robots with better and faster defensive and offensive performance against any single robot during the world championship competition. This innovative robotics design allowed Vaughn's team to win eight straight matches with high scores during Thursday's and Friday's qualifying matches, and the team advanced to first place in the 'Innovate' division of the world championship. During the Saturday session, due to a problem with the motor on one of the robots, Vaughn's team lost one of its Saturday qualifying matches, and with nine wins out of the ten matches, Vaughn's team moved from $1^{st}$ to $3^{rd}$ place in the 'Innovate' division of the world championship, and the team automatically qualified for the Saturday afternoon playoff round. In the quarter-final, the top eight teams competed, and Vaughn's team, with only one working robot, defeated a team from China and advanced to the semifinal round against AURA (a team from University of Auckland, New Zealand). In an intense, exciting semifinal game of tournament matches (best two out of three), AURA won the first match, VCAT won the $2^{nd}$ match, and during the third match AURA defeated the VCAT team and advanced to the world tournament championship matches against IFR, ultimately winning the 2017 World tournament championship.

> ➢ Finally, the Vaughn Society of Women Engineers, the Engineer Without Borders, and the new formed Society of Automotive Engineers gave presentations about their annual activities and extra-curricular involvements.



**Student Technical Paper Presentation, 1:00 pm to 3:00 pm**

Vaughn graduating students gave presentations about their capstone research projects during afternoon paper and poster sessions of the 2017 Technology Day Conference. The top 3 research papers were selected by our Industry Advisory members as the recipients of the Best Student Paper awards of this session. The winning papers included: First place research paper winner, "Portable Mechanical Ventilator for Emergency Response" by Thomas Ogungbesan and Veer Patel; second place research paper winner, "Mechanical Design Micro Air Vehicle" by Bobby Tang and Vincent Cuneo; and third place research paper winner, "Anti-Spill Cup" by Dimitri Papazoglou, Betsy I. Sanchez, and Monica A. Vanterpool.



**Students' Capstone Research Papers Presentation**

The top 2 posters (one is the NSF's project poster and one is the capstone degree project poster) were selected by our Industry Advisory members as the recipients of the Best poster awards of this session. The winning Degree Project posters included: First place poster winner, "GSM Based Smart Home Security System" by Devendra Singh. The first place NSF Learning Community poster winner is, "Comparison Modeling of Electrical and Mechanical Systems" by Denis Nekrasov.



Students' NSF and Capstone Degree Posters Session



Ninth Annual Advisory Meeting and Technology Day Conference, April 27, 2017

**The Department of Engineering and Technology expresses sincere gratitude to John Pavon for his continuous support and contributions**

John Pavon is founder and President of the Pavon Manufacturing Group and an advisory member to Vaughn's mechanical engineering and mechanical engineering technology programs. Mr. Pavon continually contributes his talent and resources to his alma mater. As an active advisory member, he provided valuable assistance and recommendations regarding new program development, laboratory enhancement, and the accreditation process for engineering and technology programs. For the past several years, Mr. Pavon established a highly successful internship program, designed specifically for Vaughn engineering and engineering technology students.

An industry leader in aerospace engineering, he has been a guest speaker for the Vaughn Industry Connection Seminar series. He delivered and addressed Vaughn community about his research topics related to "Design, ANSYS-FEA Numerical Analysis and Simulation of Damage to a Humvee Vehicle and It*s* Protection." On another occasion, he gave a dynamic presentation on "A Study of a Shaped Charge and Its Usage." Furthermore, John participated in all Vaughn's Annual Technology Day conferences, and as a judge of students' capstone research projects, he provided them with valuable assistance and recommendations.

For the past couple of years (2015 to present) Mr. Pavon made a generous donation to student engagements in robotics, UAV, and scholarly activities. As a result of the gift, Vaughn engineering students are able to participate in professional activities, conferences, and competitions, and we are grateful for his continual support in every aspect of our department and institution.

**The Engineering and Technology Department expresses sincere gratitude to Oliver Scheel for his continuous support and contributions.**

For the past several years, Mr. Scheel, who is a Director of US Didactic, served as an active advisory member of the Department of Engineering and Technology. He provided assistance and recommendations to the engineering department regarding laboratory development, program enhancement, and necessary support to engage students in professional and scholarly activities. In 2012, with his assistance the department established two new state-of-the-art thermos-fluid and mechatronics laboratories, and in 2015 and 2016 he assisted us with the establishment of a new Energy Conversion and smart grid power electronics laboratory. This lab will provide students with practical hands-on skills and will complement lecture courses in power electronics in our new electrical engineering program.

An industry leader, Mr. Scheel has been a guest speaker at the Vaughn Industry Connection Seminar series as well as at the annual manufacturing day conference and at the Summer Engineering Experience – STEM workshop session. He delivered and addressed Vaughn's students and community about topics related to Advanced Manufacturing into Cyber Physical Systems, Sustainable Energy and Manufacturing Fundamentals, Robotics and automation.

His considerable contributions to student engagement helped the engineering and technology department to advance student involvement in Robotics and UAV, EWB club activities, technical competitions (Robotics and UAV) and scholarly activities (conference papers and presentations).

The entire Vaughn community offers kudos and gratitude both to John Pavon and to Oliver Scheel, and they look forward to working with them for many years into the future.



Both Mr. Pavon's and Mr. Scheel's contributions greatly assist Vaughn engineering students' involvement in the following activities during the 2017-2018 academic year:

1. Participation in regional, national, and international VEX U Robotics Competitions.
   - From April 19-22, 62 national and international universities and colleges received invitation to participate in the 2017 VEX U World Championship in Louisville, Kentucky, Freedom Expo Center. With nine wins, Vaughn's team received 3$^{rd}$ ranking in the 'Innovate' division of the world championship and automatic qualification for the Saturday afternoon playoff round. In an intense semifinal game of tournament matches (best of two out of three); AURA won the first match, VCAT won the 2$^{nd}$ match, and

during the third match AURA defeated the VCAT team and advanced to the world tournament championship matches against IFR, ultimately winning the 2017 World tournament championship.

> In November 2017, Vaughn's Robotics club participated in the 2017 Mexico VEX in the Zone Challenge competition in the American School of Tampico, Tamaulipas, Mexico. During the playoff round, Vaughn's team remained undefeated through the quarterfinals, semifinals, final and they finished first by winning the tournament championship of this international competition. Vaughn's robotics team members consistently demonstrated persistence and drive in order to retain their title as champions of Mexico's VEX U Robotics competitions for three years in a row.

> In February, 2018, the Vaughn team hosted the Vaughn College Regional Competition, and Vaughn's robotics team won the tournament championship as well as robot and programming skills. As a result of these achievements, the Vaughn team qualified to participate in the 2018 VEX U World Robotics Championship competition.

2. In June, 2017, Vaughn's students participated in SME (society of manufacturing engineers) annual student competition in Columbus, Ohio. Vaughn's students' project titled **"Volumetric Flow Visualization System Using CW Laser & Scanning Mirrors"** by Milana Natanova, Waqas Latif, and Richa Bagelkotkar won the 'Innovation' award of 2017 ASEE Manufacturing Student Division Competition.

3. In July, 2017, Vaughn students participated in the student paper and poster competition of LACCEI2017 Conference in Boca Raton, Florida. On Thursday July 20, one of Vaughn's student team papers "**Innovative Drone Design for the AHS Micro Air Vehicle Competition"** by Bobby Tang and Utsav Shah won the 2nd place award for the student paper session competition.

4. In November, 2017, Vaughn engineering students participated in the 2017 Society of Hispanic Professional Engineers (SHPE) National Conference in Kansas City, Missouri. The Vaughn team participated in the Extreme Engineering Challenge (a non-stop, 24-hours competition) and Vaughn's student, Darwing Espinal's group, whose design topic was related to an active suspension system, won third place in the Nissan Challenge competition for a $2,500 check award.

5. In October, 2017, Vaughn's SWE club participated in the 2017 SWE Annual Conference in Austin, Texas. At the event, the Vaughn team hosted a workshop titled "Do's and Don'ts of STEM Outreach." Also, the Vaughn students participated in the SWE career fair event, and many of them received both internships and employment offers.

6. Vaughn's UAV team project was selected as one of the finalists alongside Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University to participate in the 5th annual Micro Air Vehicle (MAV) student challenge competition in the American Helicopter Society conference in Dallas Fort Worth Convention Center on May 8, 2017. Among all participating teams, only teams from the University of Maryland and Vaughn College were able to complete the remotely-operated tasks within the 10minute permitted time frame. Judges from industry and academia selected the team from the University of Maryland as the first place winner with a $1,500 check award and the team from Vaughn College was chosen as the second place winner with a $1,000 check award for the 2017 Micro Air Vehicle competition.

**2017 Summer Engineering Experience (SEE) Program**

The Summer Engineering Experiences, SEE Program is designed with an objective to enhance students' hands-on, computational, programming, communication, and problem solving skills. The 2017 Summer Engineering Experience program covered topics related to engineering computation using MATLAB and C++, bridge truss design & analysis, applied fluid & aerodynamics, and computer aided design (CAD) & additive manufacturing, and technical writing.

The following learning outcomes have been established to assess student performance in the Summer Engineering Experience program. These student outcomes are as follows:

(a) Students will demonstrate an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.
(b) Students will demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data with the use of computer applications current to industry;
(c) Students will demonstrate an ability to design and apply creativity in the design of engineering systems, components and process;
(d) Students will demonstrate an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty;
(e) Students will demonstrate an ability to communicate effectively with a range of audiences
(f) Students will demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools used in the engineering field;

Attainment of these outcomes prepares students in the SEE program for the core courses within engineering disciplines and provides them with the ability to be successful in their professional career path.

**Process for Assessment and Continuous Improvement**

The main objective of the Summer Engineering Experience (SEE) program is to provide students with the basic computational and hands-on project-based learning in numerical analysis with MATLAB and C++ programming, aerodynamics, bridge truss design & analysis, technical writing and presentation. This program not only introduces students to basic skills in developing solutions to engineering problems, but also enhances their ability to develop programs to facilitate the solution of a physical system.

The SEE program is designed to enhance student learning outcomes related to analysis, programming, design, communication and teamwork, and to prepare freshmen engineering students for the core courses within their program.

To assess the effectiveness of the SEE program, a student learning outcomes assessment process based on topics covered in the program, as well as a continuous improvement loop have been implemented. This process includes the following direct and indirect assessment process:

  ➢ Student's Evaluation Survey of SEE Program
     As an indirect measure, a rubric survey based on the contents of the SEE programs has been given to students to assess the effectiveness of the SEE programs.
  ➢ Faculty Evaluation Survey

As a direct measure, a rubric faculty evaluation survey based on student learning outcomes provides assessment of those outcomes in students' projects and presentations.

➢ <u>Monitoring and assessment of SEE students' performances within their discipline of study</u>
As a direct measure, the performance of two cohorts of students who participated in 2016 and 2017 SEE programs are monitored through core courses within their discipline of study and compared with those students who did not participate in the freshmen year of the Summer Engineering Experience program.

In assessing the SEE-STEM program, our overall goal is to ensure that at least 70 % of the students achieve a success rate of a score above satisfactory for each outcome, as indicated on the rubric. An outcome with a success rate below 70% requires action plans for improvement.

**Mapping of student outcomes vs Topics in SEE Program:** The mapping of student outcomes vs topics offered in SEE program were discussed and developed by the participating faculty members and is presented in Table 1.

**Table 1: Relationship of Topics to Student Outcomes**

| Topics | a. Math, Science, Solve Engineering | b. Experiments, Computer | c. System Design, Components, | d. Function Effectively on Team | e. Communication | f. Techniques, skills, and modern tools |
|---|---|---|---|---|---|---|
| Truss Bridge Design and Analysis | ● | ● | ● | | | |
| Computational Method with MATLAB | ● | ● | | ● | | ● |
| Computational Method with C++ | ● | ● | | ● | | ● |
| Applied Fluid and Aerodynamics | ● | | ● | ● | | |
| Computer Additive Manufacturing | | ● | ● | ● | | ● |
| Technical Writing and Presentation | | | | ● | ● | |

**Computational Method with MATLAB and C++ Application**

This topic in the SEE program provided students with some fundamental knowledge of engineering analysis and programming using both MATLAB and C++. Students were introduced to topics such as Taylor Series, finite difference, root determination, complex number, and numerical integration with application to engineering problems. Both MATLAB and C++ were introduced to students as a computing tool to generate results and facilitate the process of investigating behavior in an engineering system. Through both computational and programming (MATLAB and C++) sessions, students were introduced to the following computational processes

- Mathematical governing equation of an engineering system
- Development process of numerical formulation based on finite difference methods
- MATLAB and C++ Programming
  - How to work in MATLAB and C++ environment?
  - How to use logical control loops?
  - How to write a MATLAB and C++ program?
- Development process of numerical solution of an engineering system with MATLAB and C++ to investigate behavior of an engineering system.

In the first two weeks (Two hours per day for four days per week) students were introduced to both MATLAB and C++ programming and how to use logical control loops such as for loop, while loop, conditional loop, switch, and function to develop programs for specific application.  In the third and fourth weeks students learned how to write a program with application to engineering problems related to root determination, numerical integration, beam deformation analysis, impulsive vibration, and numerical analysis of a governing engineering equation. In the last week, students worked with faculty mentors and developed a project titled "Computational Methods of Analysis Using C++ and MATLAB" and presented their work to faculty and the Vaughn community on the last day of the summer session. Their projects were assessed by faculty members according to the following learning outcomes

- Students will demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools used in the engineering field – Both MATLAB and C++ are used as a programming and computational tool to solve analytical and numerical solution of an engineering system.

- Students will demonstrate an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics – Both the analytical and the numerical form of an engineering governing equation require knowledge of mathematics and engineering principles.

- Students will demonstrate an ability to communicate effectively with a range of audiences – Projects require both report writing and presentation.

**Introduction to Aerodynamics and Wind tunnel Testing**

In this section of SEE program, students were introduced to aerodynamics design as an example of applied engineering. They learned the basic formulation of fluid mechanics equations, which lead to application of continuity and Bernoulli's equations. Students had an opportunity to verify these equations through hands-on projects and direct measurements in the thermos-fluid laboratory. Also,

students were introduced to basic force analysis on aerodynamic vehicles with an emphasis on lift generation airfoils, as well as an opportunity to use simulation tools to better understand flow properties and their effect on the aerodynamic loads.

Through this session of SEE program students were introduced to both theoretical experimental topics relate to:
- Bernoulli's and continuity equations.
- Aerodynamics of airfoil.
- Wind tunnel testing.
- Measurements techniques in wind tunnel testing.
- Introduction to aerodynamic simulation using COMSOL Multiphysics.

In the last week, students worked with faculty mentor and developed a project titled "Applied fluid and aerodynamics" and presented their work to faculty and the Vaughn community on the last day of the summer session.

**Bridge Truss Design and Analysis**

The "Introduction to Engineering" course introduces students to some basic concepts used in solid mechanics along with simple design and hands-on application. During this course, students were given an introduction to basic concepts such as stress, strain, deformation, and Hooke's law. Applications of these concepts were then introduced to students where they studied and analyzed a basic Warren truss bridge. Students were given an opportunity to design and build a simple Warren truss bridge which was required to support the load of a truck driving over it. During this design process, students use software such as excel and CATIA. As part of the class, students were also required to write a short report explaining their design process and build a small bridge based on their design. Figure 1 shows the bridge designed by students using CATIA.



**Figure 1: CATIA design of a Warren truss bridge**

**The specifications of the bridge required to be designed are as follow:**

- Material for Truss members: A36 structural steel (yield strength, 36000 psi)
- Span a bridge : 63 ft. with 2 lanes (13 ft. each)
- The four bays, 15.75 ft. each
- Member assumed to have an initial cross-sectional area of 20 in2.
- Deal load: steel members (150lbs/cu.ft), an 8-in concrete deck(490lbs/cu.ft)
- Live load: Truck (dynamic amplification factor assumed to be 1.2)

**The specifications of the truck required to be supported by the bridge are as follow:**
- The truck has 3 axels, each one with different weight.
- The (1st) front axle of the truck exerts: 12,000 lb.
- The (2nd) central axel exerts:  48,000 lb.
- The (3rd) rear axle exerts: 50,000 lb.
- For this particular truck, the axels are separated by a distance of 15.75 ft. The same distance between each joint of the bays in the bridge.

Figure 2 shows a completed bridge made of Popsicle sticks.
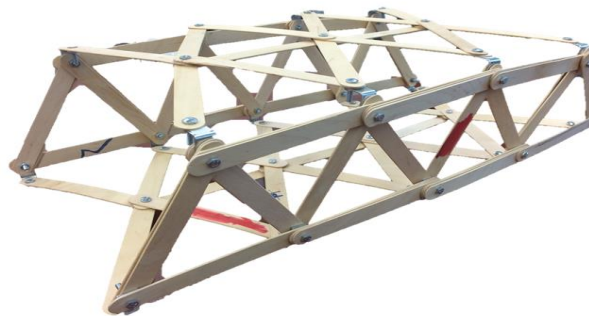


**Figure 2: Popsicle sticks Warren truss bridge**

## Computer Additive Manufacturing

For this session of the SEE program, students worked on projects related to rapid prototyping, surface modeling, and 3D scanning. The program encouraged a hands-on mindset in our students in order to foster in them a desire to participate in club activities and to develop strong industry connections during their time at Vaughn College.

Projects were developed using SolidWorks and CATIA assembly design software as a tool for virtual prototyping and visual communication. Students designed assemblies such as a bridge, car, and computer case in SolidWorks. Part fits and tolerances were optimized before committing to the expense of 3D printing.  Lectures related to MakerBot, Fortus 250 MC, and Form Labs 3D prints exposed students to new low cost accessible machines that can drastically accelerate part development. Reverse engineering was covered using the Catia Digitized Shape Editor, Quick Surface Reconstruction Workbench, and Artec Spider 3D scanner. At the end of the course students presented a PowerPoint presentation where they showcased projects related to rapid prototyping, 3D scanning, surface modeling, and product assemblies. After participation in the SEE program, students have

19

moved on to prominent roles in the UAV and Robotics clubs where they routinely employ the techniques learned in this program.

**An Introduction to Aerodynamics and Wind tunnel Testing**

In this section of the SEE program, students were introduced to aerodynamics design as an example of applied engineering. They learned the basic formulation of fluid mechanics equations, which lead to application of continuity and Bernoulli's equations. Students had an opportunity to verify these equations through hands-on projects and direct measurements in the thermos-fluid laboratory. Also, students were introduced to basic force analysis on aerodynamic vehicles, with an emphasis on lift generation airfoils as well as an opportunity to use simulation tools to better understand flow properties and their effect on the aerodynamic loads.

Through this session of the SEE program students were introduced to both theoretical and experimental topics related to:
- Bernoulli's and continuity equations.
- Aerodynamics of airfoil.
- Wind tunnel testing.
- Measurements techniques in wind tunnel testing.
- Aerodynamic simulation using COMSOL Multiphysics.

In the last week, students worked with a faculty mentor to develop a project entitled "Applied fluid and aerodynamics". On the last day of the summer session, they presented their work to faculty and to the Vaughn community.

**Technical Writing and Presentation**

Students in Engineering often need to eliminate ambiguous terminology and industry jargon from their writing, and they should learn how to write industry reports in a manner that is accessible to their targeted audience. Because most of these students have received traditional grammar instruction, in which instructors have typically focused only on "rules" of grammar, the students have often developed an antipathy to writing. Rather than having students focus in this traditional and ineffective way on what is wrong with their writing, in this class students were redirected to focus their attention more towards the ideas they need to communicate. They were shown how grammar is best learned through the process of writing, rather than through the memorization of sets of rules. Students learned how to compose clear effective sentences through syntax imitation exercises. Through the imitation of these model sentences, students experienced, for example, how combining basic sentences can produce more complex and effective writing.

Since science writing is often complex students need to learn how to hang their complex ideas on the scaffolding of simple stories with characters and actions. They are used to thinking that stories are made-up and science is fact, but linguistic research supports the idea that when people read unfamiliar information they are looking for simple stories. For example, in engineering writing, the character could be a robot or a bridge truss. Students studied models of science writing to observe and imitate this technique in their own writing.

Collaboration played a key role in the SEE Technical Writing program. Each student group contained a drafter, a reviewer and an editor, and the groups traded papers and asked questions of the other groups. Each group then presented its final report in an oral presentation.  Reading their own reports aloud and hearing others present their reports are effective ways for students to learn how to improve their own writing.

**Assessment of Students' Evaluation of SEE Program (2017 Summer STEM program)**
A rubric survey based on contents of SEE programs has been given to students to assess the effectiveness of the SEE programs.  Table 2 below provides the results of these evaluations.

**Table 2: Survey's Result and Analysis**

| Questions | Response in percent of participants (Number of participants: 7) | | | | |
|---|---|---|---|---|---|
| | Poor 1 | Fair 2 | Good 3 | Excellent 4 | Success Rate(SR); % of student with score ≥ 3 |
| 1. Rate SEE program in preparing you with the applied computational, design, & programming. | | | 2 | 5 | Score=3.71 100% |
| 2. Professor's ability in introducing you to MATLAB programing and application | | | 1 | 6 | Score=3.86 100% |
| 3. Professor's ability in introducing you to C++ programing and application | | | | 7 | Score=4.0 100% |
| 4. Professor's ability in introducing you to Fluid Mechanics and its application | | | 3 | 4 | Score=4.0 100% |
| 5. Professor's ability in introducing you to Aerodynamics and its application | | | 1 | 6 | Score=3.86 100% |
| 6. Professor's ability in introducing you to bridge design analysis and its application | | | 1 | 6 | Score=3.86 100% |
| 7. Professor's ability in introducing you to CAD and Additive manufacturing | | | | 7 | Score=4.0 100% |
| 8. Professor's ability in introducing you to technical writing and presentation | | | 2 | 5 | Score=3.71 100% |
| 9. Rate SEE program in providing you with skills in problem solving, communication, and teamwork. | | | 1 | 6 | Score=3.86 100% |
| 10. Rate SEE program in providing you with adequate knowledge and skills for your program of study. | | | 1 | 6 | Score=3.86 100% |
| 10. Rate SEE program's industry and workshop sessions in providing you with adequate technical skills. | | | 1 | 6 | Score=3.86 100% |
| **Overall average Learning Outcome Attainment** | | | **17%** | **83%** | |

**Success Rate (70% of students attaining a score greater than 3):** An outcome above a rubric score of 3 out of 4 indicates students have a good grasp of important concepts of the materials in Summer STEM Program, and our overall goal is to ensure that at least 70 % of the students (success rate) achieve a score of above 3.0 for each outcome. An outcome with a success rate below 70% required action plans for improvement.

**Analysis:** Overall, 83 percent of the survey participants rated the SEE program as excellent and 17 percent rated as good. The survey results and student comments are an indication that the SEE program has been satisfactory and provided students with a profound appreciation for engineering education.

Below are students' comments regarding SEE program

> I would recommend offering it to all freshman students because it helps prepare them for future courses. A good improvement to the program would be to provide a stipend for food for the students. Overall, the SEE program was a great experience.

> The SEE program helped me gain knowledge about my major and it helped me understand more topics that I will encounter in my upcoming classes. I would suggest creating two sessions of the SEE program, one for the freshmen and one for sophomores. I would also recommend one or two breaks between classes. I enjoyed the SEE program and I learned a lot from it.

> It was a great learning experience for the future classes in the program. I would recommend it to the new freshman student because from the program you learn a good deal of useful information that will become handy in the next semester. As for changes, I would recommend just two things, more breaks between classes to rest the mind from all the acquired information, and adding more time to the most complex classes so the hard topics can be explained and understood by the students.

> Overall the SEE program was a good opportunity for me to get a basic idea of what I may experience in my future courses, hence I would recommend offering it to other freshman students. However, to gain a better understanding of courses such as Aerodynamics and Fluid Mechanics we should have had lab activities that would allow us to apply some of the basic principles. Additionally, for courses such as CAD and Bridge Design, one hour was not enough to both go through the lecture and the activities together. Thus, I would recommend that the schedule be split into two days so that the students would have enough time for the class activities as well get a good grasp of the new material introduced.

> This program was an excellent opportunity for me to get an introduction to core courses of the engineering curriculum. This program allowed me to get a glimpse of the topics and the work load required of the mechatronics program. Although this program was effective in introducing the engineering topics, the time schedule was tightly packed leading to student fatigue. Additionally, the time allotted for each sub sections was not adequate for covering the topics per session. For a better student experience, the sub sections should be timed in such a way as to cover an good portion of material but with less sub sections in a day, that is, having two or three subsections each day which last 1.5 to 2 hours. Overall, the See Program lead to well spent one third of a summer.

> I enjoyed myself in the SEE program. I was able to work along other students with the same interests as myself without the pressure of regular school. Each one of use tried to do our best and pushed each other to do more and better. The teachers were motivated and eager to teach every day helping us with problems that we encountered and any extra material that we desired to learn. The SEE program gave me a good taste of the subjects that I will be taking on the following semesters of my college career, and helped me better develop tools like computer aided design and programming that I will be implementing on extracurricular activities and in my future job.

**Recommendations:** After reviewing students' comments, we are adding more time to Summer STEM program and extending it from 5 weeks to six weeks as of summer 2018. Also, we will add more hands-on classes related to aerodynamics and robotics.

**Learning Outcomes Evaluation of SEE program by Faculty**

The following learning outcomes have been established to assess student performance in the Summer Engineering Experience program during student presentations on the last day of the program. These student outcomes are as follows:

(a) Students will demonstrate an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.
(b) Students will demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data with the use of computer applications current to industry;
(c) Students will demonstrate an ability to design and apply creativity in the design of engineering systems, components and process;
(d) Students will demonstrate an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty;
(e) Students will demonstrate an ability to communicate effectively with a range of audiences

As it can be observed in table 1, each group project is used to measure specific student learning outcomes related to their research topic that has been presented by students during the last day of SEE program on June 30, 2017. The results for four groups of reports on the presentations, as demonstrated in the table below, are used to assess the effectiveness of the SEE program's learning outcomes (Rating: 1=worst and 5=best). Four faculty judges were selected to assess student attainment of these learning outcomes, and data in the table below shows the average values of those evaluations.

**Table 1: Students' projects learning outcomes assessment**

| Title of Group Projects | Student Learning Outcomes Rating: 1=worst, 5=best | | | | |
|---|---|---|---|---|---|
| | **a** | **b** | **c** | **d** | **e** |
| 1.  Computational Method Using MATLAB and C++ | 4.5 | | 4.75 | 4.50 | 4.40 |
| 2.  Fluid Mechanics and Aerodynamics | 3.5 | 4 | 5 | | 4.50 |
| 3.  Bridge Truss Design and Analysis | 4.00 | 4.60 | | 3.50 | 4.75 |
| 4.  CAD and CAM (Additive Manufacturing) | | 4.60 | 4.50 | 4.00 | 3.90 |
| **Average Outcomes Attainment** | **4.00** | **4.40** | **4.75** | **4.00** | **4.39** |

**Rating:  1=Needs Significant Improvement, 2=Needs some improvement, 3=Average, 4=Good, 5=Excellent**
Attainment of these outcomes prepares students in the SEE program for the core courses within engineering disciplines and provides them with the ability to be successful in their professional career path. The judges' surveys and these results will be discussed in the ASEE Conference. .

**Monitoring and assessing SEE's student performance within their discipline of study**

As a measure to assess the effectiveness of the SEE program, the performance of two cohorts of students who participated in 2016 and 2017 SEE programs is monitored through core courses within their discipline of study and compared with those students who did not participate in the freshmen year of the Summer Engineering Experience program. As shown in table 3 (2016 cohort) and table 4 (2017 cohort) below, the results for both cohorts of the SEE program, through various engineering courses, are compared with total students within each course who received a grade of B or better.

**Table 3: 2016 cohort of SEE program**

| Course | Total Number of Students | Number of 2016 SEE Students | % of total Students with B or better | % of SEE Students With B or better |
|---|---|---|---|---|
| MEE220, Mechanics of Materials | 24 | 6 | 10/24=41% | 5/6=83% |
| MEE235, Material Science | 26 | 5 | 11/26=42% | 3/5=60% |
| MEE345, Fluid Mechanics | 15 | 5 | 8/15=53% | 3/5=60% |
| MEE365, Machine Design | 17 | 6 | 9/17=59% | 5/6=83% |
| ELE220, Electronic Circuits | 16 | 6 | 12/16=75% | 5/6=83% |
| ELE220L, Electronic Circuits (Lab) | 16 | 6 | 13/16=81% | 6/6=100% |
| ELE230, Digital Systems Design | 11 | 5 | 8/11=73% | 4/5=80% |

**Table 4: 2017 cohort of SEE program**

| Course | Total Number of Students | Number of 2017 SEE Students | % of total Students with B or better | % of SEE Students With B or better |
|---|---|---|---|---|
| MEE210, Thermodynamics | 28 | 8 | 52% | 88% |
| EGR230, Mechanical Testing | 7 | 6 | 85% | 100% |
| MEE220, Mechanics of Materials | 24 | 6 | 7/24=29% | 4/6=67% |
| MEE235, Material Science and Failure Analysis | 21 | 5 | 9/21=43% | 4/5=80% |
| MEE340, Computational Method | 15 | 7 | 9/15=60% | 5/7=71% |
| MEE345, Fluid Mechanics | 15 | 5 | 8/15=53% | 3/5=60% |
| ELE220, Electronic Circuits | 18 | 6 | 15/18=83% | 6/6=100% |
| ELE230L, Electronic Circuits (Lab) | 18 | 6 | 15/18=83% | 6/6=100% |
| ELE230, Digital Systems Design | 12 | 4 | 8/12=67% | 3/4=75% |

As shown in table above, the program has been successfully implemented and students of this program had better performance through core courses within their discipline of study than those who did not participate in the SEE program. Also, many of first and second cohort students of the SEE program are now active in professional development, robotics and UAV activities.

**Friday's Seminars and Workshops**

Friday's session of SEE program is designated for technical seminars and workshops. This session is designed to enhance students' learning outcomes related to critical thinking, problem solving, and life-long learning. Given the rapid pace of technological change, the Friday seminar series and workshop helps students in the SEE program to develop a mind-set receptive to changes in technology and prepares them for future challenges.

Seminar #1
**Date:** Friday, June 2, 2017, 10 am -3 pm
**Presenter:** Mr. Michel Lévis, Application Engineer, Quanser
**Topic:** The Quanser Aero Experiments

The objective of this workshop was to introduce the students' to the large, industrially-relevant fields of rapid controls prototyping, instrumentation, and control systems. Demonstrations using Quanser hardware were used to show how the hardware is actually implemented.

Rapid Control Prototyping (RCP) is used in various industries and was introduced using the MathWorks MATLAB/Simulink and the Quanser QUARC software. Using the Quanser Q2-USB data acquisition device, the time-saving benefits of graphical design and code generation were demonstrated using a simple analog loopback test.

The field of instrumentation was then addressed. Using the National Instruments LabVIEW software, Mr. Levis demonstrated how RCP-based tools can be used to interface to hardware systems. The Quanser AERO two-degree of freedom benchtop helicopter system was used to illustrate how to use RCP software to interface to the pitch position sensor and actuate the rotors.

Building on the concepts taught in RCP and instrumentation, the Quanser AERO helicopter was used again to introduce control systems and to regulate the position of the pitch angle. The different elements in a control system and the most common types of control were first described: on/off control and PID. A PID controller was designed step-by-step in MATLAB/Simulink and ran on the AERO (using the QUARC software). The way in which each term in PID affects the position response of the flight system was then illustrated: the derivative term attenuates the oscillations and the integrator removes steady-state error between the desired command and the measured.

This workshop ended with a presentation on Unmanned Vehicle Systems (UVS) to demonstrate how the concepts of RCP, instrumentation, and control systems can be used in these applications. The Quanser Qbot 2 mobile Unmanned Ground Vehicle (UGV) was used to show students different types of sensors (e.g. camera), and how RCP software can target remote systems and can be used for localization. The talk ended with a system overview and video of the Quanser Qball 2 Unmanned Aerial Vehicle (UAV).

Seminar #2
**Date:** Friday, June 9, 2017, 10 pm – 2 pm
**Presenter:** Mr. Oliver N. Scheel, Director of US Didactic, Inc.
**Topic:** Sustainable Energy and Advanced Manufacturing Workshop

The President of US Didactic talked about the Sustainable Energy and Manufacturing Fundamentals and System Applications at Vaughn College. Students who participated in the SEE Workshop were introduced to Fundamentals & Applications pertaining to Solar Photovoltaics, Solar Thermal Techniques, DFIG Wind Turbines, Small Wind DC Generators, and Renewable Energy Distribution and its relationship to Intelligent Micro Grids. The new Sustainable Energy courses and lab activities also provide an excellent complement to the existing Power Systems Option.

The second part of the workshop focused on the integration of new technology with current manufacturing practices. With most of the participants currently enrolled in the Mechatronics Program, the conversation quickly focused on Cyber Physical Systems, aka the Internet of Things (IOT), and the close connection to Smart Factory 4.0 concepts. The discussion touched on numerous processes including communications with transducers & actuators, subsystems, fault detection and analysis, linked facilities, and other anticipated changes for students to consider as they prepare for their entry into the workforce.

**Date:** Friday, June 16, 2017, 10 am – 2 pm
**Presenter:** Mr. Waseem Hussain, Vice President of Union Crate
**Topic:** Python Programming

In this workshop session Mr. Waseem Hossain talked about Python programming and how python can be used to create object-oriented programming. He showed students how to create a file and use flow chart in developing and writing a python program for specific application. During the workshop session, students received one to one hands-on training working in the python environment in order to create an object-oriented code to conduct engineering analysis and generate results.



**Waseem Hussain Co-Founder & VP of Union Crate Start-up Company**

Seminar #4
**Date:** Friday, June 23, 2017, 10 am – 2 pm
**Presenter:** Prof. Manuel Jesus
**Topic:** CAD and Additive Manufacturing

Prof. Manuel Jesus, a faculty member in the engineering and technology department with extensive background in CAD and additive manufacturing, conducted a workshop covering 3D scanning and surface modeling with CATIA and the Artec range of 3D scanners. SEE students also had several lectures regarding 3D scanning, 3D printing, and some surface modeling labs in Solid works as part of their course offerings. By the time the scanning workshop began, students were familiar with this technology and they were eager to learn in a dedicated hands-on workshop.

Three dimensional scanning is used by the automotive, aerospace, and entertainment fields. Scans are acquired from real world objects, sculpted forms, and human anatomy. The acquired scan data is then used as a reference model for part creation. Modern manufacturing requires CAD data sets and CATIA CAD software is an essential tool for 3D scan based part development. CATIA has

27

many tools to facilitate part design from 3D scans with strict tolerances. In this workshop a 3D scanned part was converted into a solid model from an older physical part for use in a modern Product Lifecycle Management (PLM) system.

The 3D scanning process started with capturing scan data composed entirely of triangles representing the 3d mesh surface of the object. Model development utilized many of CATIA's Workbench applications. Students first used the Digitized Shape Editor Workbench where a 3D scan point cloud was prepared for use in CATIA. Here students cleaned up the scan by filling in any holes in the surface geometry and optimizing mesh density though a reduction process called decimation. Cross sections shapes were then extracted with reference planes placed laterally along the wing structure. The sections were then taken into the Quick Surface Reconstruction Workbench where students extracted reference curves. Although the curves were clean representations of the wing shape, students further optimized curves to develop the solid model. Students then transferred to the Sketcher, Generative Shape Design, and Part Design Workbenches where they worked to insure good curvature continuity. Surfaces were then made using the Generative Shape Design Workbench. Once a surface body was constructed, the surface was converted to a solid model in the Part Design Workbench. Students were shown how boss, shell, rib, and other parametric features could be used to make the final component for manufacturing.

Students learned and practiced this workflow through the use of instructor developed exercise files, and they were encouraged to work on scans of their own. Students have already utilized this technology in our 3D Printing and Innovation lab for degree projects and personal research projects. As an instructor, I think it is vital to share technology that optimizes development resources and empowers student creativity. I was grateful to share my research and experience with 3D scanning in this workshop.

## LABORATORIES UPGRADE AND ENHANCEMENT

For the past several years, as a result of the Title III grant funding support, the engineering technology department has been able to establish several state-of-the-art-laboratories such as the Thermo-Fluid lab, the Robotics and Control System lab, the automation lab, the Energy Conversion and Smart Grid Power Systems lab, and the 3D innovation Center. These new facilities and upgraded existing facilities contribute to student success in both scholarly activities and technical competitions.

The current title III grant "Developing Guided Articulated Completion Pathways in Leading Edge Aeronautics and Aviation Careers for Hispanic and Low-Income Students," will further enable the engineering department to develop an advanced manufacturing program as well as laboratories associated with this program. This new grant will allow the department to enhance the current additive manufacturing center and the CNC machining lab. It will further assist the department with development of state-of-the-art composite manufacturing and UAS laboratories. Vaughn's faculty and staff are confident that through the effective and efficient use of grant funding, the college will successfully accomplish its vision for the future.

The department developed, upgraded and enhanced the following laboratories.

➢ **Energy Conversion and Smart Grid Power Systems Laboratory**

As part of US Department of Education (Title III HIS-STEM) grant, the engineering and technology department established a state-of-the-art **Energy Conversion and Smart Grid Power Systems Laboratory** in Fall 2015 ($350,000 power electronics equipment) with the objective of providing students in EE and Mechatronic Engineering programs with hands-on experience in smart grid and power electronics. This lab will complement lecture courses in Electromagnetism (ELE323), Electric Machines (ELE325), Power Electronics (ELE451), and Introduction to Power System (ELE452). Additionally, this lab provides students with opportunities to observe and demonstrate fundamental theory pertaining to Electrical Machines, Power Electronics, Motor Drives Circuits & Controllers, contemporary techniques in Power Generation, Power Transmission, Power Distribution, and Energy Management of Load Consumption.

> ➤ **NEW Machine Shop**

In the fall of 2015, based on 2014 & 2015 annual spring advisory meetings feedback, the engineering and technology department purchased a HASS VF-2SS CNC milling and cutting machine with all accessories. Currently, the engineering and technology department is in the process of establishing a new CNC machine shop to facilitate the implementation process of a new manufacturing engineering technology program. The new title III grant provides necessary funding to support the completion of the new machine shop, by adding a lathe machine (Okuma Genos), Coordinate Measuring Machine (CMM) for manufacturing part inspection, and Mastercam (Industry standard Computer Aided Milling software used for part and CNC program development) as well as the renovation of the new CNC machine shop.

Both faculty and students should be able to use CNC machine shop for manufacturing parts for the laboratory testing samples, CAM and Prismatic Machining course assignments, and parts and components for their capstone degree projects. Also, this lab will be used to teach and conduct hands-on experiments for CNC programming, machining, and the manufacturing process.

➢ **Robotics and Control System Laboratory**

This lab is used to teach laboratory courses such as MCE101 (Introduction to Robotics), ELE326 (Microprocessor), ELE350 (Control System), MCE420 (Mechatronics II-Robotics) and has dedicated seating to instruct 15-20 students. This lab maintains equipment related to control system, Intelitek robotics, microprocessor, and mobile robots.

➢ **3D prototyping innovation center**

The 3D printing center was developed as a resource to foster student engagement in academic projects and personal designs. Students are encouraged to develop and print parts at zero cost; however, 3D printed content is closely monitored by faculty. Introductory CAD classes familiarize students with the product development process, through a focus on assembly development for 3D printing.

The design for this facility was inspired by the Maker Space trend in STEM education. However, while researching peer institutions, we discovered an overreliance on the use of a sole vendor for all 3D printing endeavors. The engineering and technology department opted to broaden its selections, since the 3D printing marketplace is evolving at such a swift pace. The rapid prototyping lab employs a diverse range of technology consisting of 3D printers, desktop CNC, and 3D scanners from companies such as Makerbot, Creality, Form Labs, 3D Systems, Stratasys, Carbide 3D, Artec, and Mark Forged. Our 3D printing methods range from Fused Deposition Modeling (FDM) machines to higher end industrial Stereo lithography (SLA) machines capable of mass production.

Such a diverse range of technology has empowered students with the skills to develop faster design iterations during project development. Students will often start with a low fidelity FDM print then progress to a high fidelity SLA print. At the end of the process, they gain hands on experience required to contribute to Robotics Club activities and to professional industry opportunities.

The support of the new Title III grant will assist the department in the complete establishment of Vaughn's state-of-the-art 3D prototyping innovation center by adding a Form Labs Fusion (SLA Powder based SLS printer capable of printing fully assembled products with minimal cleanup), 3D Systems HD3600 3D printer, Fusion laser engraver, and a Forged Desktop Injection Molding Machine. This center will be used to teach hands-on computer-aided design and 3D printing manufacturing courses within all engineering and technology programs. Also, this center can be used by Capstone Degree Project students and UAV and Robotics clubs to design and build mechanical parts for their projects.

## ➢ Mechanical Testing Laboratory

This lab is equipped with Measurement Group, Inc. strain measurement hardware and measuring devices for instructional capability in stress analysis. Students can perform basic experiments in plane stress, torsion, and bending to verify the basic equations in strength of materials. In fall 2015, the engineering and technology department purchased two desktop tensile machines and two furnaces for the Mechanical Testing Lab. This laboratory course complements lecture courses in solid mechanics concentration in our mechanical engineering program and provides our students with hands-on experiences in evaluating mechanical properties. This lab is equipped with a tensile machine, torsion machine, fatigue machine, impact machine, hardness machine, vibration testing equipment, strain measurement hardware and devices for stress analysis. The support of the new Title III grant will assist the department in enhancing the current lab by adding equipment related to RAPTOR imaging flaw detector, digital ultrasonic flaw detector, and Instron material test system.

➢ **Composite Manufacturing center**

As part of title III grant funding support, the college is establishing a State-of-the-art composite manufacturing center at the Aviation Training Institute (ATI) building to support the implementation process of both the composite design certificate program and the future BS in advanced manufacturing program as an additional concentration within the existing Mechanical Engineering Technology program. As shown in table below, this center will be equipped with practical hands-on composite manufacturing equipment that provide students with knowledge and skills current with today's manufacturing industry standards.

| Composite Manufacturing EQUIPMENT |
| --- |
| 1.   Oven (for curing composite layup) |
| 2.   Autoclave |
| 3.   Ply cutting table |
| 4.   Two hot bonders |
| 5.   Five Vacuum bagging kits |
| 6.   Two vacuum pump and accessories |
| 7.   Supplies for composite manufacturing (resin, fabric, tapes, films, peel ply) |

Also, testing equipment such as, RAPTOR Imaging Flaw Detector, EPOCH 650 Digital Ultrasonic Flaw Detector, and Micro II-Compact PCI AE system will be used to study nondestructive failure.



Autoclave       Oven for Composite Manufacturing       Vacuum bagging kit



Phased array ultrasonic testing equipment (flaw detector)       Eddy current testing equipment

33

- **Electronics Laboratory**

The department of engineering and technology ensures that laboratories for all programs are adequately equipped with training stations, supplies, experimentation kits, general and special test equipment to ensure that student learning is enhanced in all courses through appropriate hands-on skills directly related to the current needs of the industry.

The department has recently acquired development kits for AVR ATMega328p microcontrollers. These kits include wide array of sensors such as temperature, shock, vibration, infrared, humidity, smoke, carbon monoxide, laser, LDR, passive mic, color recognizer, and a variety of output devices such as LCD displays, multicolor leds, servo motors with encoders, ultrasonic transmitter-receiver, laser emitter and DC motors. These development kits have been instrumental in helping students apply their knowledge of microcontrollers to Internet of things (IoT) solutions in remote controlling and remote autonomous sensing.
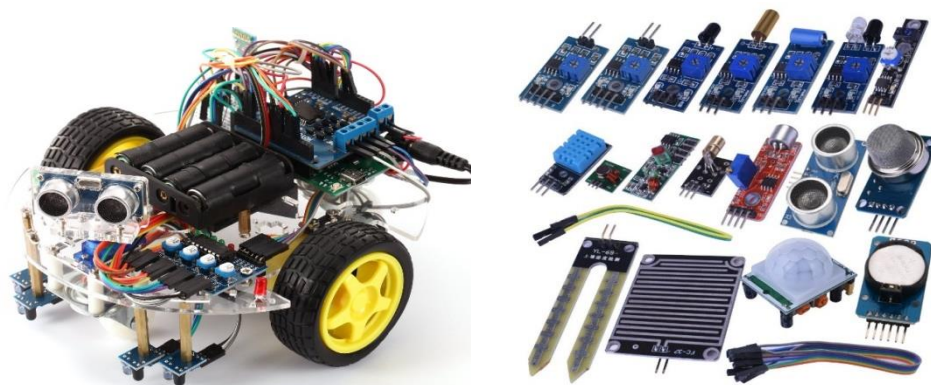


Additionally, the department has purchased several autonomous line-follower robot development kits that students use to design different types of rover systems. These rovers can be line-followers, sense-and-avoid, or all inclusive simultaneous localization and mapping (SLAM) bots by sensing the environment through ultrasonic distance measuring and LIDAR ranging. The department also utilizes Microchip PIC microcontroller evaluation boards and burn-in platforms.

Courses in DC circuits, AC circuits and Communication systems utilize LabVolt Facet line of trainer boards. Analog communications trainer boards are used to help students understand concepts of digital communications, pulse amplitude modulation (PAM) signal generation, demodulation, PAM time division multiplexing (TDM), pulse time modulated (PTM) signal demodulation and generation, pulse code modulation (PCM) generation and demodulation, signal time-division multiplexing, and Noise Channel Bandwidth.
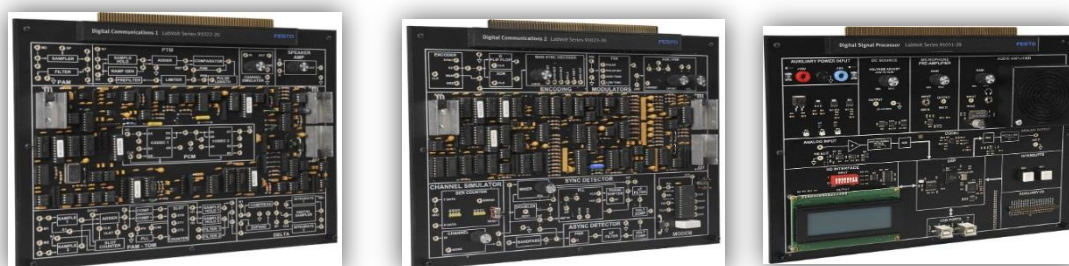
Digital communication boards provide hands-on skills in encoding and decoding frequency shift keying (FSK) signal generation, asynchronous detection, synchronous detection, phase shift keying (PSK) signal generation and synchronous detection, amplitude shift keying (ASK) signal generation and asynchronous detection effects of noise on ASK and PSK and operation of an FSK and differential phase shift keying (DPSK) modem.



The Digital Signal Processor circuit board introduces students to the vast field of digital signal processing (DSP) and its applications. The board is designed around a modern DSP and includes all of the peripherals and accessories required to run multiple DSP applications.



Fundamentals of AC circuits board are used to help with concepts of magnetism, AC waveform generation, AC amplitude measurements, current and impedance measuring, phase angle, series vs parallel circuits, inductive and capacitive reactance and impedance, relay transformer windings, mutual inductance, turns and voltage ratios, RC circuits, RC time constants and RC/RL Wave shapes.

The program also utilizes recently purchased FEEDBACK 56-200 microwave trainer systems that help students in measurement of frequency and wavelength, diode detector law, measurement of voltage standing wave ratio (VSWR), impedance matching and applications of typical waveguide components such as directional coupler, E-plane tee, H-plane tee, hybrid tee, waveguide to coaxial transformer, and horn antennas as feed elements for radar reflectors, as well as microwave radio link transmit and receive antennas.



35
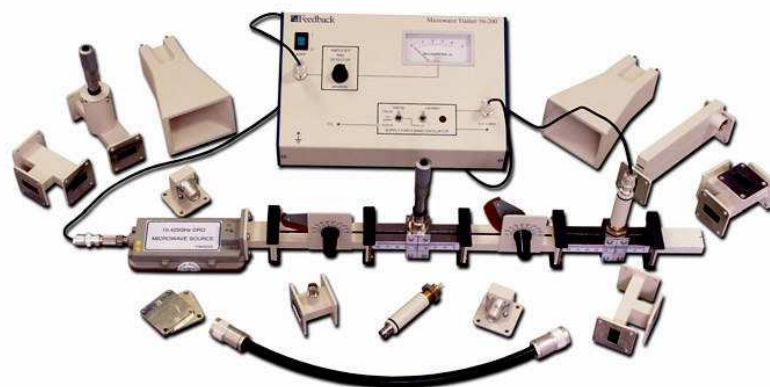
The department also recently replaced soldering stations with a set of six Hakko soldering and circuit rework stations from Technitools® and a surface-mount soldering and rework station in order to give students hands-on skills in soldering and desoldering in accordance with IPC-A-610 – Acceptability of Electronics Assemblies and FAA Advisory Circular 43.13 - Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair.



The program continues to utilize recently purchased function generators, high voltage power supplies, spectrum analyzers and oscilloscopes to enhance student hands-on skills in foundational concepts of DC circuits, AC circuits, electronic devices, digital electronics, communication systems, navigation systems, pulse systems and radar systems.



36

## ➤ Thermo-fluid Laboratory

This lab has dedicated seating to instruct 15-20 students. In this lab, students have the opportunity to conduct a wide range of experiments related to thermal and fluids sciences, such as measuring aerodynamic drag, liquids densities, hydrostatic pressure, Boyle-Marriott's law, surface tension of liquids, flows in liquids & gases, heat exchangers efficiencies and free and forced heat convection coefficients. This laboratory course complements lecture classes such as fluid mechanics, aerodynamics, and heat transfer.

In fall 2015, the engineering and technology department placed a purchase order for a High Speed Camera and CW laser; this equipment provides an important benefit to the thermo-fluid laboratory, and it will be used to complement the courses (MEE260-Aerodynamics, MEE360-Propulsion Power for Aircraft and Rocket Engines, EGR375-ThermoFluid) in our new mechanical engineering program. In fall 2016, the CAD import module has been added to COMSOL finite element package to allow students to build geometric model from any existing CAD software.
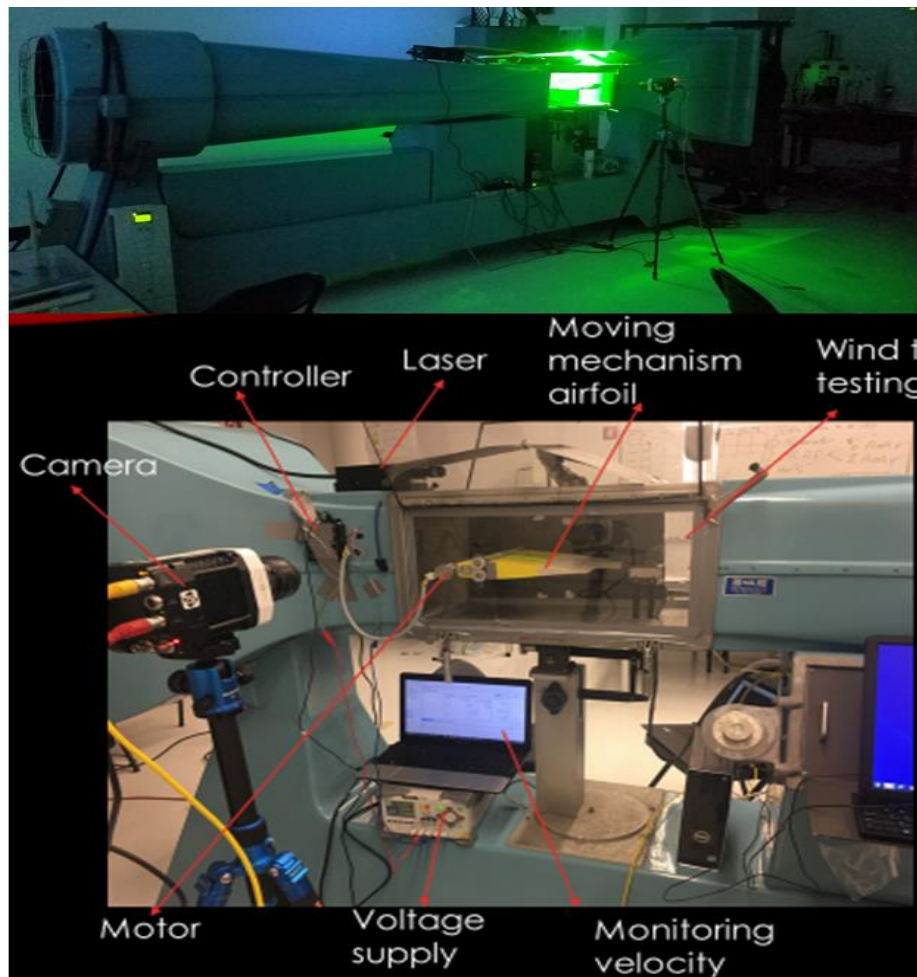
**Industry Advisory Council**

At Vaughn College, the industry advisory members have a pivotal role in program delivery and thus in students' subsequent success. The industry advisory members work closely with the faculty members of the engineering and technology department in developing new course offerings and program modifications. Their valuable recommendations and comments continuously make our program delivery stronger and more competitive with the growing demand of today's technology. Furthermore, the close partnership with these industrial companies, such as Sikorsky, Northrop Grumman Corporation, Defense Contract Management Agency, Corning, Lockheed Martin, SciMax Technologies, RCM-Tech, Rockwell Collins, Pavon Manufacturing Group, FAA, CPI-Aerospace, Wunderlich-Malec, Kedrion Biopharma, US Didactic, Con-Edison, and MTA, allow our students to explore a career or an internship opportunity with top engineering enterprises.

**Internship Programs**

Vaughn's internship program is a key part of an engineering curriculum to prepare students for the workplace. For the past several years, our students were involved with both summer, and school year internship programs with top engineering companies such as Daimler, John Deere, NASA, Sikorsky, Northrop Grumman Corporation, Lockheed Martin, RCM-Tech, Rockwell Collins, Federal Aviation Administration (FAA), Alken Industries, Cummins Engine, MTA, GE, Pall Corp., Pavon Manufacturing Group, Raytheon, Safe Flight Instruments, Toyota, Robotics Education and Competition Foundation (RECF), and Naval Research Enterprise Internship Program (NREIP). These internships provided them with a greater appreciation for engineering education and expanded their hands-on and career-building experiences. As a result of these internships, many of our graduates are currently working with these companies as new advisory members for our programs, and assisting our current students in pursuing internships with these companies.

**Faculty Professional Engagements and Workshop Participation**

To improve the quality and effectiveness of instructional delivery and student learning, the engineering and technology department encourages faculty members to participate in conferences and workshops designed to enhance faculty's understanding of new technological discoveries and innovations to maintain teaching quality. For the past few years our faculty members have been active participants in many educational and technical conferences and workshops such as the American Society for Engineering Education (ASEE), Latin American and Caribbean Consortium of Engineering Institutions (LACCEI), Aircrafts Electronics Association (AEA), Institute of Electrical and Electronics Engineers (IEEE), American Institute of Aeronautics and Astronautics (AIAA), Society for Experimental Mechanics (SEM), and American Society of Mechanical Engineers (ASME). Also, faculty were involved with the development and implementation process of two new mechanical and electrical engineering programs, laboratory development/enhancement, and learning communities for NSF scholarship recipients.

During the calendar year 2015–2016, faculty in the engineering and technology department participated in the following professional engagements and workshops:

### Hossein Rahemi

1. On January 27, 2017, along with Vaughn's robotics team, he hosted the VEX U regional qualifier at Vaughn College. A total of ten college teams participated in this event and Vaughn's robotics team won the 2017 VEX U 'Excellence' award of this event.

2. On January 28, 2017, along with Vaughn's robotics team, he hosted the VEX High School regional robotics qualifier at Vaughn College. A total of 41 regional high schools from Queens, Brooklyn, Bronx, Nassau, and Suffolk counties attended the January state qualifier VEX Robotics Competition at Vaughn College. An alliance of the Farmingdale High School and The Harvey School won the tournament championship, while a team from Jericho High School won the 'Excellence' Award. Both tournament champions and 'Excellence' award recipients are qualified to participate in the New York State Vex Championships.

3. On Feb 3, 2017, as an advisor to Vaughn's robotics team, he participated in the 2017 College of Southern Maryland (CSM) Regional Qualifier, and Vaughn's robotics team won tournament champion at this regional competition.

4. In spring 2017, he submitted an initial progress report for the title III STEM grant "Developing Guided Articulated Completion Pathways in Leading Edge Aeronautics and Aviation Careers for Hispanic and Low-Income Students" that includes information/updates on facilities, faculty and staff, and the development process of stackable manufacturing certificate programs, on the as well as process for developing the advanced manufacturing program.

5. He published the ninth Annual Vaughn College Journal of Engineering and Technology (VCJET). This journal includes annual department's activities, laboratories upgrade and development, faculty and student professional engagements, graduate success stories, industry tours, engineering seminar series, industry connection seminar series and student technical research papers (April 2017).

6. He hosted the ninth Annual Vaughn College Technology Day Conference on April 27, 2017. At the morning session, he introduced the advisory members to the contents of a new purposed advanced manufacturing program. The afternoon session was devoted to student capstone research project presentations and the poster session. The participants included industry advisory members from Sikorsky Aircraft Corporation, Corning Incorporated, SciMax Technologies, The Composite Prototyping Center, Pavon Manufacturing Group, Defense Contract Management Agency (DCMA), Honeywell, U.S. Didactic, Wunderlich-Malec, Con-Edison, JetBlue, BELCAN, and City Tech CUNY.

7. As a PI of the NSF S-STEM grant ($575,000 funded by NSF), he monitored NSF learning community activities and engaged the 4th years NSF scholarship recipients in professional engagements related to conference participation, conference poster competitions, and Robotics/UAV club activities & competitions.

8. From spring to fall 2017, he submitted a monthly progress report for the title III STEM grant "Developing Guided Articulated Completion Pathways in Leading Edge Aeronautics and Aviation Careers for Hispanic and Low-Income Students" that includes information/updates on facilities, faculty and staff, and the development process of the stackable manufacturing certificate programs as well as the process for developing the advanced manufacturing program.

9. On Feb 2, 2017, the engineering and technology department chair presented an update on the department and the new title III STEM grant activities to the Academic Policy Committee of the Board of Trustees. The presentation included ME & EE enrollment, new additive manufacturing and CNC machining certificates development process, facilities upgrade, and updates on: the 2nd annual manufacturing day conference, the industry connection seminar series, the engineering seminar series, and student participation in professional activities and technical competitions.

10. He participated as Vaughn's robotics team adviser in the 2017 VEX U World Robotics College Championship. From April 19-22, 62 national and international universities and colleges received an invitation to participate in the 2017 VEX U World Championship in Louisville, Kentucky at the Freedom Expo Center. Invitation to the VEX U Robotics World championship is only granted to a team that is a tournament champion or 'Excellence' award recipient of a regional competition. Vaughn's Robotics team was 2016 tournament champion of the international congress of Technologies of Information and Communication, tournament champion of the College of Southern Maryland (CSM) Regional Qualifier, and recipient of 'Excellence' Award of Vaughn College Regional Robotics Competition—which qualified the College to participate in the 2017 VEX U World Championship. For the fourth year in a row, Vaughn's robotics team was able to advance to the playoff round of the VEX U World Championship. During Thursday, Friday, and Saturday qualifying matches, Vaughn's team competed against 10 teams and they won nine out of the ten matches. With nine wins, Vaughn's team ranked 3rd in the 'Innovate' division of the world championship and automatically qualified for the Saturday afternoon playoff round. In an intense semifinal game of tournament matches (best of two out of three) AURA won the first match, VCAT won the 2nd match, and during the third match AURA defeated the VCAT team and advanced to the world tournament championship, ultimately winning the 2017 World tournament championship.

11. He submitted the second annual progress report for both ME and EE programs including information/updates on: new/refurbished facilities, faculty and staff, and preparations for ABET evaluation has been submitted to the NYSED on September 2017. Every September an annual report needs to be submitted to the NYSED until the department receives EAC-ABET accreditation for both of these programs.

12. On Saturday May 6, 2017, he organized the engineering and technology department hosting of several drone workshops such as CAD Modeling of Quadcopters, Build a Drone, and Programming with Python in order to celebrate International Drone Day. This event allowed visitors and students to design, build, and test their own drones in the netted flying arena of the college hangar.

13. Under his oversight, Vaughn's UAV team project was selected as one of the finalists beside Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University to participate in the 5$^{th}$ annual Micro Air Vehicle (MAV) student challenge competition in Dallas Fort Worth Convention Center on May 8, 2017. Among all participating teams only teams from the University of Maryland and Vaughn College were able to complete the remotely-operated tasks within the 10 minute time restriction. For the 2017 Micro Air Vehicle competition, judges from industry and academia selected the team from the University of Maryland for first place with a $1,500 check award and the team from Vaughn College was chosen for second place with a $1,000 check award.

14. On Thursday May 2, 2017, the Engineering and Technology department chair presented department activities to the Academic Policy Committee of the Board of Trustees; those were as follows:

    ➢ Update on the 2017 VEX U World championship; Vaughn's robotics team finished the competition with 3$^{rd}$ place ranking out of 62 invited teams.
    ➢ Update on Vaughn's ninth Annual Technology Day Conference that took place on April 27, 2017; students' paper and poster sessions award recipients
    ➢ Update on drone workshop hosted by the UAV team to celebrate International Drone Day on May 6, 2017.
    ➢ Update on UAV team preparation and participation as finalists for both autonomous and manual categories in the American Helicopter Society (AHS) Micro-Air Vehicle Competition in Dallas, Texas, May 8, 2017.
    ➢ Update on 2017 Summer Engineering Experience (SEE) program designed to prepare freshmen students for the core courses within engineering programs. The SEE program is designed with an objective to enhance students' hands-on, computational, programming, communication, and problem solving skills.
    ➢ Update on HIS-STEM grant activities, certificate programs and laboratory development & enhancement.
    ➢ Update on the spring industry connection seminar series.
    ➢ Update on student involvement in professional societies, conference participation, presentations, and publications.

15. For the second year in a row, he conducted a Summer Engineering Experience program (SEE) to prepare first-year students for engineering programs. The five-week SEE program was offered in the summer 2017. Monday through Thursday (from 8:00 am to 4:00 pm)

41

sessions were devoted to lectures and hands-on classes covering topics related to engineering computation using MATLAB and C++, aerodynamics, bridge truss design & analysis, technical writing and presentation. The Friday's session of the SEE program was designated for technical seminars and workshops. This session is designed to enhance students' learning outcomes related to critical thinking, problem solving, and life-long learning.

16. On June 28, 2017, he participated in the 2017 ASEE annual conference and presented a paper entitled "Summer Engineering Experience (SEE) Program to Prepare Freshman Students for Engineering Studies." The paper and presentation detailed the development, implementation, and learning outcomes assessment process of the 2017 SEE program.

17. From July 18-21, as an advisor to Vaughn's student projects and as a Liaison of LACCEI board, he participated in LACCEI 2017 Conference in Boca Raton, Florida. On Thursday July 20, one of our student team papers "**Innovative Drone Design for the AHS Micro Air Vehicle Competition"** by Bobby Tang and Utsav Shah was selected as a finalist and has was presented to the international conference audience during the student paper competition session of LACCEI2017. Out of ten finalist papers, Vaughn's student paper received the 2nd place award in this session.

18. Hosting Vaughn's 3rd Annual Manufacturing Day Conference on October 27, 2017 to celebrate National Manufacturing Month, he invited four industry leaders and two faculty members to address invited guests and the Vaughn community on manufacturing innovation in the area of additive manufacturing, cyber physical systems, 3D printing, composites, CNC machining and automation in manufacturing. In a parallel session, from 11 am to 2:00 pm, Vaughn's UAV and Robotics clubs organized and hosted workshops on building a drone, robotics design, and autonomous programming for the high school students from Freeport, Bayside, Garden City and the South Country school districts, as well as The Wheatley School and Thomas Edison.

19. **Composite Certificate Program**: As Project Director of HIS-STEM title III grant and with input of composite prototype curriculum designer, he developed five courses (total of twelve credits), listed below, toward composite certificate program

    1. **Introduction to Engineering Materials,** 3 credits, 3 lecture hours– Semester 1
    2. **Introduction to Composite Materials,** 3 credits, 3 lecture hours – Semester 1
    3. **Introduction to Composite Manufacturing,** 2 credits, 1 lecture hour & 3 lab hours –Semester 2
    4. **Mold Fabrication and Adhesive Bonding of Composite and Metals,** 2 credits, 1 lecture hour & 3 lab hours –Semester 2
    5. **Non-Destructive Testing Techniques for Composite Materials,** 2 credits, 1 lecture hour & 3 lab hours –Semester 2

In September, the Project Director, with the assistance of the Grants Manager, completed an application for a Composite Manufacturing Certificate program which was submitted to the NY State Education Department for review and approval. This certificate program has a total of twelve credits and will provide students with an analysis of composite materials along with hands-on experience in composite manufacturing. Students will also be introduced to mold fabrication and adhesive bonding of composite and metals, which is an integral part of composite manufacturing. Students will also be exposed to the most

common and latest Non-Destructive Inspection (NDI) equipment and methods and techniques used in the field of composite inspection.

20. **Computer Aided Design for Additive and Subtractive Manufacturing Certificate Program**: As Project Director of HIS-STEM title III grant and with the input of the 3D/CNC Curriculum Designer, he developed four courses (total of 8 credits) towards a Computer Aided Design for Additive and Subtractive Manufacturing Certificate program. The certificate program will comprise of the following courses:

    1. **Computer Aided Design with Solidworks,** 2 credits, 1 lecture hour & 3 lab hours – Semester 1
    2. **CATIA Fundamentals,** 2 credits, 1 lecture hour & 3 lab hours – Semester 1
    3. **Computer Graphics for Additive Manufacturing,** 2 credits, 1 lecture hour & 3 lab hours –Semester 2
    4. **CATIA for Prismatic Machining and Subtractive Manufacturing,** 2 credits, 1 lecture hour & 3 lab hours –Semester 2

    In early November, the Project Director, with the assistance of the Grants Manager, completed an application for a 3D Additive and Subtractive Manufacturing Certificate program which was submitted to the NY State Education Department for review and approval. This certificate program has a total of eight credits and will provide students with both knowledge of computer-aided design, along with hands-on experience in 3D printing additive manufacturing.

21. **Industry Connection Seminar Series:** The department Chair organized and invited several industry leaders as guest speakers for the fall and spring Industry Connection Seminar Series. The name, date, and topic of presentation for those who accepted our invitation are as follows:

    1. **Aviation Engine Trends — Transitioning engine from high power and large fuel consumption to more efficient engines,** Mr. Dominic Visciotti, Team Leader Assembly Engineering at CYIENT, Oct 10, 2017.
    2. **Quality Management Systems,** Mr. Manny Santana, Quality Assurance Specialist, DCMA, Nov 7, 2017.
    3. **NASA's Internships Program and other career opportunities,** Mr. Matthew Pearce, NASA Education Programs Specialist, Nov 9, 2017.
    4. **Taming The Advanced Scoring Platform (ASP) a research and development tool for Mechanical Scoring & Separation of glass**, Mr. Michael Joseph, Sr. Project Engineer, Corning Inc, Nov 16, 2017.
    5. **Avionics Innovation Initiatives**, Dr. Denis Bonnet, Chief Innovation Officer of Thales Avionics, January 29, 2018.

22. **Supplemental Instructors (SI):** In an effort to increase learning effectiveness, as part of the Hispanic-Serving Institution HSI STEM grant, the Supplemental Instructor (SI) program was developed to further enhance and improve student understanding through the fundamental courses in engineering and engineering technology programs. In fall 2017, nine talented SIs, who have already completed the fundamental courses, were selected to sit-in on designated courses, with instructors, to serve as designated Supplemental Instructors. The student supplemental instructors are assigned with the task of reviewing class lectures,

conducting problem solving sessions and communicating with the faculty member about areas where students need reinforcement in order to be successful in the course.

23. On Monday Oct 30, 2017, as an advisory board of NYIT's Mechanical Engineering program, he attended a luncheon with the ABET visiting team. This was an informative meeting regarding how to prepare graduate for the workplace. The discussion evolved around the importance of internship, hands-on skills and technology that is current with today's industry trends.

24. On October 17, 2017, Dr. Rahemi presented department activities to the Academic Policy Committee of the Board of Trustees; these were as follows:

   ➢ Update on drone workshop hosted by UAV team to celebrate International Drone Day on May 6, 2017.
   ➢ Update on participation of Vaughn's UAV team as one of the finalists along with Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University in the 5th annual AHS Micro Air Vehicle (MAV) student challenge competition in Dallas Fort Worth Convention Center on May 8, 2017. Vaughn's UAV team successfully completed the task and won the 2nd place award in this challenging competition.
   ➢ Update on Enrollment statistics and on the implementation process for the new mechanical and electrical engineering programs.
   ➢ Update on HSI-STEM title III grant activities including information regarding staff development, laboratory development, stackable manufacturing certificate programs, meeting with staff and manufacturing curriculum faculty, equipment and facility renovation.
   ➢ Update on hosting the third Annual Manufacturing Day Conference on Friday October 27, 2017.
   ➢ Update on fall's Engineering Seminar and Industry Connection Seminar series.
   ➢ Update on student involvement in professional societies (ASEE, LACEEI, SEM, and SWE), conference participation, presentations and publications.
   ➢ Update on Robotics, UAV, and SWE, EWB clubs professional activities and competitions.
   ➢ Update on student placement (full-time position, internship, graduate programs)

25. Department meetings with engineering and technology faculty regarding preparation for 2019 ABET reaccreditation of Mechatronic Engineering and all other Engineering Technology programs. The items covered are as follow:

   ➢ Developing Program Self-Study reports.
   ➢ Distribution and collection of exit, alumni, employer, and internship surveys. Surveys need to be analyzed based on success rate criteria to assess attainment of student learning outcomes.
   ➢ Keep three samples (Good, average, and poor) of each course task for ABET site visit display materials.

- ➢ FCARs, capstone degree project, employer evaluation surveys and internship supervisor surveys will be used as direct measures of assessment of student learning outcomes.
- ➢ Exit, alumni, and student course evaluation surveys will be used as indirect measures of assessment of student learning outcomes.
- ➢ Course Level Continuous Improvement: Develop course-level and student-level action plans and revisit shortcoming student learning outcomes in subsequent tasks for improvement.
- ➢ Program Level Continuous Improvement: Analyze results of FCARs, employer and internship supervisor surveys and develop program-level action plans for any shortcoming student learning outcomes through the program. Organize meetings with faculty, industry advisory members, and student learning outcomes (SLO) committee to discuss, develop, and implement necessary action plans to improve program's low performing outcomes.

26. In November 2017, Dr. Rahemi and seven members of Vaughn's Robotics club traveled to Mexico to participate in the 2017 Mexico VEX U Reeduca Robotics competition as part of the Torneo VEX-Reeduca de la Zona Noreste 2017-2018. Fifteen teams, including Vaughn College Robotics team, participated in Mexico's VEX in the Zone Challenge competition in the American School of Tampico, Tamaulipas, Mexico. During the playoff round, Vaughn's team remained undefeated through the quarterfinals and semifinals, and finished first by winning the tournament championship of this international competition. For three years in a row, Vaughn's robotics team members consistently demonstrated persistence and drive in order to retain their title as champions of Mexico's VEX U Robotics competition.

27. In mid November, under the direction of Dr. Rahemi, we recived approval from the NYSED regarding our composite manufacturing certificate program, and in early January we recived approval from the NYSED regarding our Computer Aided Design for Additive and Subtractive Manufacturing Certificate program. The department will begin to offer courses within this certificate program after completing composite laboratory and 3D center renovation and purchasing supporting equipment.


**Amir Elzawawy**
1. Advised UAV club in micro-UAV student competition as one of the finalist during AHS annual forum, Fort Worth, TX, May 2017. Vaughn College UAV team was second in this competition.
2. Administrated and monitored students in NSF-STEM Scholarships program. The program encompasses more than two cohorts of 18 students for the period of four academic years of each cohort.
3. Advised and mentored multiple teams of students to develop research journal papers for VCJET 2017. The projects were presented in the afternoon session of 9th Annual Vaughn College Technology Day Conference on April 27, 2016.
4. Assisted Vaughn's UAV club in hosting multiple UAV workshops as part of International Drone Day hosted by Vaughn College on Saturday, May 6, 2016.
5. Attended ASEE 124th Annual Conference in Columbus, OH from June 25th to 28th.
6. Advised students on their poster presentation in "Make it!" session at ASEE annual conference.
7. Participated in SME (Society of Manufacturing Engineers) annual student competition

in Columbus, OH on June 27. Vaughn students' project titled **"Volumetric Flow Visualization System Using CW Laser & Scanning Mirrors"** by Milana Natanova, Waqas Latif, and Richa Bagelkotkar received the 'Innovation' award of 2017 ASEE Manufacturing Student Division Competition.

8. In July 2017, UAV team participated at LACCEI annual conference in Boca Raton, FL. The team won the second place in the student paper competition.
9. In Summer 2017, developed and taught a module for Summer Engineering Experience (SEE) Program. The program is titled "Introduction to Aerodynamics and Wind Tunnel Testing".
10. In Summer 2017, worked on developing new mechanical engineering program course titled "Propulsion Power for Aircraft and Rocket Engines", which was offered on fall 2017.
11. Advised students in the UAV/AIAA students chapter, while adding more networking events to strengthen student professional exposure.
12. Served as a member of Middle States Steering Committee in addition to co-chairing subcommittee of Standard 8 "Student Admission and Retention" as part of Middle States Accreditation process.
13. Hosted multiple workshops for High School Students including workshops on CAD modeling and Building UAV's and Programming using Python during Vaughn College annual manufacturing day on Oct. 27$^{th}$ 2017.
14. Summer 2017, started a sequence of online courses in the field of Robotics and UAV.
15. Organized a field trip for the NSF program in cooperation with the career services office; student visited Curtiss-Wright manufacturing facility on December 2017.
16. Continued working with UAV club on the club activities including the upcoming semester activities, evaluated events and workshops given to high school students at Vaughn College's Manufacturing Day, as well as workshops for girl scouts at the Cradle of aviation.
17. On December 12, 2017, attended Cradle of Aviation event to support NY-Long Island Manufacturing Industry. The event was sponsored by HIA-LI and organized by Manufacturing Consortium of Long Island.
18. Attended NSF Grant Proposal Writing online training January 15$^{th}$, 2018 through March 15$^{th}$, 2018.

### Shouling He

1. Served as a program coordinator of Mechatronics Engineering (MCE) Program; evaluated students' qualifications for the program applications; assessed department exit surveys, alumni surveys, internship supervisor surveys and employer surveys; developed and collected faculty course assessments and written the program assessment report for the MCE program; and prepared documents for Middle States Accreditation board visiting in April 2017 and ABET board visiting in Fall 2019.
2. Worked on faculty course assessment cards (FCARs) and developed 12 FCARs to evaluate the courses taught in fall 2017.
3. Advisor for four groups of student capstone projects with the presentation at 2017 VCATD Conference and the publications in 2017 VCJET (2$^{st}$-3$^{rd}$ places in paper competition.) One group joined the 5$^{th}$ Annual Micro Air Vehicle Student Challenge and one group presented the project paper at 2017 LACCEI conference.
4. Advisor for one student project entitled "Volumetric Flow Visualization System Using CW Laser & Scanning Mirrors" in the *Maker It* section of 2017 ASEE Annual Conference, with 'Innovation' Award in Manufacturing Competition.

5. Participated 2017 ASEE Annual Conference and presented the paper "SEE Program-A Program to Prepare Freshmen Students for Engineering Studies with Dr. Rahemi and Dr. Ducharme.

6. Participated in IEEE Regional Workshop, From Machine Learning to Deep Learning: "How Artificial Intelligence Is Changing the World," May 12, 2017, LIU-Brooklyn, NY.

7. Participated Two-Day Workshop held by Rockwell Automation Company: Rockwell Automation "On the Move to Learn" Allen-Bradley PLCs, May 17-18, 2017, Meadowlands, NJ.

8. Participated the NSF-RET Program held at Texas A&M University and worked a master teacher for 6 weeks, wrote the report and presentation entitled "Multi-Sensors for Robot Teaming using Raspberry Pi and VEX Robotics Construction Kit;" the paper has been accepted by ASEE 2018 Annual Conference, June 26-28, 2018, Salty Lake, UT.

9. Presented the educational research with the title of "Development of Teaming Robots for Engineering Design Education – Cross-platform System" at the 2018 NSF-RET Program Workshop, March 15, 2018, TAMU, College Station, Texas.

10. Wrote an educational research paper, "Teaching Linux and ROS for Mechatronics Engineering Students," the abstract of which has been accepted by 2018 Frontiers in Education – "Foster Innovation through Diversity," October 3-6, 2018, San Jose, CA,

11. Worked with SWE students and wrote the educational research paper entitled "Initiating Engineering Learning for Minority Students in Elementary Schools," which was presented at 2017 ASEE Mid-Atlantic Conference, October 6-7, Cornel Penn State Berks, PA.

12. Worked as a club advisor at the 2017 Society of Women Engineers (SWE) Annual Conference, October 26-28, 2016, Austin, Texas, assisting SWE Vaughn Chapter Students in holding a workshop at the world's largest conference for women in engineering, and helped female students with job interview process. Eleven Vaughn students received twelve job interviews, three internship offers, two job offers, plus three internship offers which were extended as job offers.

13. Worked as a club advisor to help the SWE club to gain $5000 grant from Con Edison Company for SWE STEAM education programs at Vaughn College, and advised students for workshop organizations and club activities; helped the club for the tour of RCM Technology facility and worked as an advisor for the partnership with the Physics Department of Queens Community College for the development of data acquisition board for ray detectors and data analysis.

14. Worked as a mentor for three NSF-STEM Scholarship groups (one in 2017 and two in 2018) in their research. One student won the first award in the poster section at the 2017 Vaughn College Annual Technology Day (VCATD) Conference.

15. Worked with students on an educational research paper "Self-designed Drone for Engineering Education." This paper was presented at the 2017 LACCEI Conference.

16. Worked as a course instructor for the Community Learning Program to develop collaborative learning mode with Dr. Ducharme (English) and Mr. Jesus (Solid Work) and supervised student presentations; brought learning community students to the Queens Maker Faire to gain the knowledge on building a robot and 3D printing a product.

17. Worked to improve the course, MCE420, Autonomous Mobile Robots with the ROS operating system and the basic principle of mobile robot mapping and localization so that the students in Mechatronics Engineering program can learn current knowledge in the area of Robotics.

18. Improved the course, ELE326/ELE326L, Microprocessors, by adding the basic concepts of GPUs and Computer Vision. Particularly, the course projects allowed students to learn new knowledge in microprocessors and share their understandings at the presentation to enhance their capability for

life-long learning.

19. Worked as a faculty-member at the open house in the spring and fall 2017, introducing the Mechatronics Engineering program and the SWE Vaughn College Chapter, and a host faculty for the high/middle school students to visit the PLC lab and Power Electronic Lab in summer 2017.

## Yougashwar Budhoo

1. Became the faculty advisor and worked with students to develop and establish the Society of Automotive Engineers (SAE) chapter at Vaughn College in Fall 2017
2. Became the faculty advisor for the SHPE club at Vaughn College.
3. Accompanied ten students to the SHPE conference. Advised them during the Nissan design challenge in Kansas City, Missouri, Nov 3, 2017
4. Developed syllabi for courses to be taught in the new certificate in composite manufacturing program.
5. On July 17, 2017, attended a five-day course on "Adhesive Bonding of Metals and Composites" at Abaris training facility in Reno Nevada.
6. On June 21, 2017, attended a five-day course on "Nondestructive Inspection Techniques" at Abaris training facility in Reno Nevada.
7. On May 14, 2017, attended a five-days course on "Composite Manufacture and Repair" at Abaris training facility in Reno Nevada.
8. Mentored two groups of NSF-STEM Scholarship recipients in their research work.
9. Adviser for students' poster presentation entitled "The Jungle" at the LACCEI 2017 Conference, in Boca Raton, Florida, July 19, 2017
10. Adviser for students' technical conference paper entitled "Effect of the 3-D Printing process on the Mechanical Properties of Materials" at the SEM 2017 Conference, in Indianapolis, Indiana, June 12, 2017
11. Presented a short course on the analysis of composite materials for high school students at the Composite Prototyping Center, Plainville N.Y on November 19 , 2016
12. Developed and presented an Introduction to CATIA course (35hrs.) for Performance Plastics LTD. at the Composite Prototyping Center, Plainville N.Y from July to August, 2016.
13. Developed teaching material for CDE 490 (CATIA Composite Product Design) which was taught during fall of 2016.
14. Completed course level assessment for courses in the Mechanical Engineering Technology (MET) Program
15. Distributed, collected, and analyzed surveys (exit, alumni, internship, and employer) from our students, alumni and employers for 2016.
16. Started working on the program level assessment for the MET program.

## Rex Wong

1. On March 18, 2017 attended a Civic Leadership Forum of New York sponsored by APAPA (American Public Affair for Asian Pacific Islander), Honorable Keynote Speakers including Congresswoman Grace Meng, state senator Toby Stavisky, and District Leader Justin Yu.
2. May 2017, served as a member of the new EE faculty search committee for Vaughn College.
3. September 23, 2017 attended the 2017 IEEE North Jersey Advanced Communications Symposium (NJACS-2017), one day seminar at Stevens Institute of Technology, in

Hoboken, NJ. The symposium consisted of several keynote presentations and a parallel poster session. The symposium program covered advanced topics in AI, big data, machine learning, deep learning, and applications.

4. On September 7, 2017 attended CST Antenna Simulation workshop, an online webinar about using CST software tool to simulate the functions and performance of the mobile device antenna in wireless signal reception and processing.

5. On September 24, 2017 attended Maker Fair site in Queens Fresh Meadow Park with some students from Vaughn. It is a scientific & technological carnival which promotes the concept of self-made, hands-on craftsmanship, in the wake of 3D printing, to host desktop fabrication and customized manufacturing.

6. Oct. 20/21, 2017 attended the Workshop: "Revamping Robotics Education to meet 21st Century Workforce Needs," held in Bay Community College, Escanaba, Michigan. This workshop is offered to faculty members of two or four year institutions and designed for the instructors who are interested in adding their experience in Industrial Robotics and who wish to revamp existing or develop new courses in Industrial Robotics.

7. On Oct. 24, 2017 attended Facebook Tech Talk on the topic of "Cyber Security for Automobiles & Building in Security," provided by DHS science & technology Directorate.

8. On Oct. 27, 2017 attended Vaughn's 3$^{rd}$ Annual Manufacturing Day, a one-day event for networking with industrial leaders in aviation and manufacturing. Keynote speakers included Albert Bunshaft, senior VP of Dassault Systemes.

9. Attended annual Industry Connection seminars at Vaughn College, on Nov. 7 & 9, 2017, which provided an opportunity for students and alumni to connect and consult.

10. Participated in EE curriculum committee meeting for the newly NYSED approved Electrical Engineering program and made necessary modifications for implementing this program in the fall 2016.

11. Submitted a journal paper which has been accepted and published in 2016 ASEE Journal of Manufacturing Division. The title is "MAKER: An Entry-level Robotic System Design Project for K-12 and Undergraduates". This is the follow-up for the NSF funded summer research program, RET (Research for Teachers) held at Texas A & M University from June 8 until July 18, 2015. This program is particularly focused on research experiences for teachers in Mechatronics, Robotics, and Industrial Automation.

12. Attended ASEE 123rd Annual Conference & Exposition in New Orleans, Louisiana, to present a poster in Makers Poster Session, June 28, 2016.

13. Represented Vaughn College at the energy committee meeting of Queens Chamber of Commerce at Astoria, NY, May 19, 2016. This event could lead to helping students who are studying power/energy to establish industrial relationships.

14. Participated in drone workshop hosted by the UAV team to celebrate International Drone Day on May 7, 2016.

15. Attended Society of Women Engineers event to support SWE club activities on April 28, 2016.

16. Attended Engineers Without Borders event at Vaughn to support EWB club agendas and activities, April 15, 2016.

17. Attended the 2-day RoboUniverse Conference held at Javits Center, NYC, April 10-11, 2016. This conference integrated robotics, drone, and 3D printing into one topic.

18. Attended Industry Connection Seminar by Dr. Tahani Amer, NASA Supervisor of Engineering Project Management, on Thursday, March 24, 2016. The topic was:

"Computational Fluid Dynamics to Project Management and Opportunities for Students at NASA."

19. Participated in VEX Sky-Rise competition as judge at Freeport High school on Long Island, NY on Feb. 6, 2016.

20. Participated in VEX Sky-Rise competition as judge at Vaughn campus in Feb. 13, 2016.

21. Presented my NSF funded summer research program entitled "A Learning Module Dedicated to Enhance the Study of Robotics and Mechatronics" conducted at Texas A&M University at the fall Engineering Seminar Series on Oct. 1, 2015.

## Sundari Ramabhotla

1. Faculty Advisor of IEEE at Vaughn College (March 2018 – Present)
2. Participant in Leaning Community in Engineering & Technology department, Vaughn College, January 2018 - Present.
3. Attendee at Women in Aviation 2nd meeting at Vaughn College, February 2018.
   *Paper Review*
4. **Journal Reviewer "**Strategic Placements of PMUs for Power Network Observability Considering Redundancy Measurement," for Measurement, Sustainable Energy, Grids and Networks, Elsevier, March 13th, 2018.
5. **Conference Reviewer** in the area of Power System Architectures & Distribution Systems, Power Electronics, Batteries & Energy Storage, Renewable & alternative energy sources for INTELEC, 22th - 26th October 2017, Queensland, Australia.
   *Professional Memberships*
6. **Institute of Electrical and Electronics Engineers** (IEEE)
   o **Faculty Advisor** (2018 – Present)
   o **IEEE Member** (2014 - Present)
   o **Young Professional Member** (2014 - Present)
   o Presenter, Reviewer in Conferences and Journal transactions.
7. **Society of Women Engineers** (SWE)
   o **Life Member** (2018 - Present): Received Life Member award at SWE17 conference for excellence and active participation in SWE.
   o **Professional Member** (2016 - Present): Active participation in SWE
   o **Scholarship Reviewer for SWE Scholarship Program** – reviewer for scholarships to provide financial assistance for education to women matriculating in accredited baccalaureate or graduate programs, in preparation for careers as engineers and computer scientists.
8. **Wind Energy Student Association** (WESA)
   o **Faculty Support** (January 2017 – December 2017)
   o Actively participated and advised the undergraduate students on resumes, job skills and interview skills on renewable energy and energy needs.
   *Outreach and Diversity*
9. Presenter and Volunteer in the "***Invent It Build It 2017***", ALWE2017/WE17, Austin, TX, October 26-28, 2017.
10. Judge and Presenter with the STEM related projects on for the Coronado High School students, Lubbock, TX, October 4th, 2017.
11. Presenter and Volunteer in the "***Tech Loves Athletics***", Texas Tech University & Davis Park, Lubbock September 22nd, 2017.

12. Presenter and Volunteer in the "***Tech Loves Health***", Covenant Children's Hospital, Red Cross & Doctors without Borders & Texas Tech University, Lubbock September 21st, 2017.
13. Presenter and Volunteer in the "***Tech Loves Education***", Children's Home of Lubbock & Texas Tech University, Lubbock September 20th, 2017.
14. Presenter and Volunteer in the "***Tech Loves Lubbock Dream Center***", Women's Protective Services, Lubbock Dream Center & Texas Tech University, Lubbock September 20th, 2017.
15. Judge and Presenter with projects related to Science, Technology, Engineering and Mathematics (STEM) related activities in the "***Girl Scouts Volunteering***", Society of Women Engineers, Lubbock, September 16th, 2017.
16. Participant in Texas Tech University, NWI outreach to educate the local Elementary, middle and High schools on wind energy, renewable energy, etc. January 2016 – December 2017.
17. Presenter on "**Solar energy**" to the Estacado High school students in "***Run on the Wind and Generation TECH***," camp, Texas Tech University, Lubbock, July 10th - 14th, 2017.
18. Judge in the Wind Turbine, sail car and Solar home competition for the Estacado High school students in "***Run on the Wind and Generation TECH***," Texas Tech University, Lubbock camp July 10th - 14th, 2017.
19. Attendee at NREL's WISDEM Workshop, North American Wind Energy Academy (NAWEA) Symposium, September 26th - 29th, 2017, Iowa State University, Ames, Iowa.
20. Attendee at PSU's XTurb Workshop, North American Wind Energy Academy (NAWEA) Symposium, September 26th - 29th, 2017, Iowa State University, Ames, Iowa.

**Manuel Jesus**
1. Attended Bronx NYC Public School STEM day and presented career options to students (April 2017)
2. Printed 3D models for the Robotics club and other Vaughn College students using the Fortus 250mc 3d Printer and Form 2 printers. (Ongoing)
3. Taught Catia Advanced Surface and Shape Design Course, Ascenbridge Solutions (June 2017)
4. Taught HASS CNC Machine Operation and Tool Setting, HASS HFO Allendale Machinery, (August 2017)
5. Worked as a faculty instructor for 2017 Summer Engineering Experience (SEE), taught students CAM and additive manufacturing.
6. Presented at Vaughn College Manufacturing Day Event (October 2017)
7. Attended Long Island Manufacturing Association Meeting (August 2017)
8. Attended "Character Design For Video Games and VR," Game Art Institute, Los Angles (May 2017)
9. Attended "Character Sculpting ZBrush," Game Art Institute, Los Angles (June 2017)
10. Attended "3-D Character and Creature Design," Game Art Institute, Los Angles (August 2017)
11. Attended ICEM Surf Class A Surfacing Fundamentals, BETA CAE Systems (Nov 2017)
12. Developed and taught Zion "Cradles to Careers" SolidWorks STEM Middle School outreach program (Dec 2017)
13. Judged VEX Robotics Regional High School Competition, (Jan 2018)
14. Ongoing researcher and developer of CNC and 3D printing related labs. (Jan, 2018)
15. Attended Mastercam Workshop (April, 2017)

**Khalid Mouaouya**

1. Worked as a faculty instructor for 2017 Summer Engineering Experience (SEE), taught students engineering mechanics.
2. Participated In ASEE2017 Annual Conference and Exhibition, Columbus, Ohio, June 25 to 28.
3. Participated with Vaughn's student and faculty in LACCEI 2017 conference at Boca Raton, Florida, July 18 to 21, 2017.
4. Participated with Vaughn's Robotics team in the fall Mexico's VEX U Reeduca Robotics competition as part of the Torneo VEX-Reeduca de la Zona Noreste 2017-2018, Tampico, Mexico, November 11, 2017.
5. Participated in all Vaughn's spring and fall 2017 Industry Connection Seminar Series, and Engineering Seminar Series.
6. Participated in the 3rd annual Vaughn Manufacturing Day conference on Oct. 28, 2017.
7. Advised Engineers Without Borders (EBR) club, fall 2015-present.

**Mudassar Minhas**

1. Completed Project Management Professional (PMP) Exam Prep course for the PMP Exam - 35 Contact Hours from PMI REP #4082 (Dec 2017 – Jan 2018)
2. Served as Chair for committee on "Planning Resources Allocation and Institutional Renewal" under Middle States Accreditation Steering Committee for Vaughn College (Sep 2016 – Apr 2017).
3. Served on committee for revising Vaughn College Faculty Handbook. (Sep 2016 – Apr 2017)
4. Completed improvement modifications to lab equipment and lab exercises for Radar Systems, Laboratory Standard Practices, Integrated Avionics Systems, and Pulse Systems. (Fall 2017)
5. Developed Arduino C programming and sensor integration exercises for Microprocessors course. Purchased a wide array of sensors, actuators and servos and implemented IoT integration and remote sensing using Arduino. (Fall 2017)
6. Attended Seminars:
   - "Innovative Isolated RS-485, SPI and LVDS Communications" by Analog Devices, Jan 10, 2018
   - "Optimizing SMIC 40LL and 40ULP Designs for Speed and Energy Efficiency" by Synopsys, Jan 3, 2018
   - "Taking the next level in Multicopter Solutions" by Infeneon Technologies, Nov 9, 2017
   - "RF Discrete: Beyond Product Performance" by Infeneon Technologies, Nov 2, 2017
   - "Fundamentals on PCB design" by Mentor Graphics, Oct 31, 2017
   - "Half Bridge and Gate Driver Measurements" by Tektronix, Oct 10, 2017
   - "Automotive power supply ICs: The enabler for your success" by Infeneon Technologies, Sep 29, 2017
   - "NFC technology: Opening a world of Opportunities in IoT" by STMicroelectronics, Jun 21, 2017
   - "Why audio matters for Bluetooth Applications" by Sierra Wireless, Apr 26, 2017.

In order to prepare students for the growing demands of today's technology and to aid them in their future careers, the Engineering and Technology Department at Vaughn College adopted a set of in-class and out-of-class academic activities reflective of ongoing technological change. These activities are designed with the intention of instilling in students an awareness of the importance of lifelong learning in meeting their future professional challenges.

Whatever path our engineering and engineering technology students choose, their Vaughn education thus provides them with an edge for success.

**Michael A. Joseph, II; Class of 1982**
**Sr. Project Engineer**
**Corning Incorporated**
**Associate's Degree in Aeronautical Engineering Technology, 1982**
**Bachelor's Degree in Mechanical Engineering, 1988**

Innovation can be as simple as making small improvements to existing technology. I have often spent hours scouring junk yards and hock shops for inexpensive parts to use in my personal and professional projects. In my youth, I rebuilt old radios and bikes, and I restored my first car, a 1969 Buick Electra 225 Custom Sport Coupe. Much of what I have patented, or contributed to a patent, has thus come from making incremental improvements on existing components. This tendency of mine has also led to my leadership in the creation of large-scale designs for multi-million dollar projects.

My father liked to tell the story about how, as a child of 5, I announced "I want to be an engineer!" He showed me how to use a saw, and we cut out a crude boat from a piece of 2x4 pine wood with two 45 degree cuts forming the bow. A few weeks later, I presented him with a palm sized 2x4 with Entenmanns Bakery string interlaced between a series of nails. I'm not sure if my father knew what to make my palm-top computer mock-up made back in 1967.

I have long been a fan of simplicity in engineering. GM engineers integrated a simple power plant, turbo, intercooler, driveline, & fuel injection, with a basic sedan platform (Buick Regal) to produce a world class Ferrari, for a fraction of the price. The engineer's insight into the optimal combination of components and resulting synergy led to the development of the legendary black Buick Grand National, the fastest car sold in the US in 1987.

After graduating with an Associate's degree in Aeronautical Engineering Technology from Vaughn College in 1982, I began my professional career with K&K Engineering & Manufacturing drafting electro-mechanical devices. I then worked for Gibbs & Cox, Naval Architects and Marine Engineers as a Jr. CADD designer on the US Navy's Arleigh Burke Destroyer program. I continued my education, graduating with a Bachelors of Engineering in ME from Pratt Institute.

My work with Johnson & Johnson/ETHICON began in 1988. While working on process engineering and high speed medical fiber manufacturing, I also worked on gaining knowledge of

53

computer science by taking graduate courses at the University of Georgia and by auditing an Expert Systems course at the Georgia Institute of Technology. In 1989, I built Ethicon's first production line Knowledge Based computer troubleshooting system, the third application of that advanced J&J technology. I also introduced digital video and optical disk storage for process analysis.

I began my career with Corning Incorporated in 1995 as a Project Engineer. My firsts include mechanical cutting of Gorilla ® Glass, Scoreless Cutting of Willow ® Glass, Thermal Cutting of next generation strengthened glasses, and automatic cutting of LCD glass with irregular contours. I have built dozens of devices to aid in manufacturing for Corning Incorporated. I've earned 9 US patents and published over 22 research papers, two of which I presented to the students at Vaughn College of Aeronautics. (VCOA)

I continued my education with graduate Systems Engineering courses at Rensselaer Polytechnic Institute (RPI), and Glass and Ceramic Fractography at Alfred University. These classes have kept my skills current and my mind sharp.

VCOA gave me a good foundation in engineering, design, and mathematics that I continue to build upon. VCOA is also where I first learned about the history of aviation. In the school library, I read about the Tuskegee Airmen's Commander, General Benjamin O. Davis, Jr., a man I later befriended. At VCOA, I met and listened to many aviation legends, such as WWI Double Ace and past VCOA president George A. Vaughn, Jr. and General James H. Doolittle, who earned the second PhD granted by MIT in Aeronautical Engineering. Thirty-six years later, I still remember the words of my Differential Equations professor which continue to guide my development:

*"Any concept, once rigorously defined, generates its own associated properties."*
*Dr. Ming Hwang*
*Differential Equations Professor*
*Vaughn College of Aeronautics & Technology (Academy of Aeronautics)*

**Yougashwar Budhoo, Class of 2005**
**BS in Mechanical Engineering Technology, Vaughn College, 2005**
**MS in Mechanical Engineering, CUNY, 2007**
**Ph.D. in Mechanical Engineering, CUNY, 2010**

I graduated from Vaughn in 2005 with a bachelor of science degree in mechanical engineering technology. Later, I earned a master's degree in mechanical engineering from The City University of New York (CUNY) and a doctorate from the CUNY Graduate Center. I am now back at Vaughn as a tenured assistant professor in the engineering and technology department. I continue to be motivated by my love of learning and my commitment to Vaughn's students.

I am happy to be back teaching at Vaughn, because as a student, I always felt that people here cared about me as an individual. Similarly, I now want to inspire Vaughn students to reach for and achieve their highest goals. I believe that the college's tight-knit community offers a great learning opportunity. The low student-to-teacher ratio allows us to know all our students by name, and we come to understand their needs and strengths. In the transmittal of knowledge to our students, we are also committed to being current in all of the latest technologies. An example of this currency is Vaughn's annual Technology Day and industry advisory council meeting. An industry group comprised of companies like Sikorsky, Corning, and Con Edison, and learning institutions like LaGuardia Community College and New York City College of Technology come together to evaluate Vaughn's programs, courses, laboratories, and software in order to ensure that the Vaughn College programs offer the best and most current education possible.

I believe the key to student success is for instructors to pay close attention to students and to be responsive to what 'works' for them in the moment. If the attentiveness is there, what works will naturally follow.

Today, my primary focus is on composite material study. I love the cutting-edge nature of research in composite and its vast practical applications in aerospace and other engineering manufacturing industries. Because of their flexibility, the design and application possibilities of composites have reached new heights and they have the capacity to revolutionize industry. Currently, I am working with Dr. Hossein Rahemi, Chair of Engineering at VCOA, in developing a certificate in composite material program which should be offered in the near future.

Working with the dynamic team of Vaughn professors, my philosophy is to commit to excellence in the present moment, and then the future will take care of itself.

**Muhammad Noman, Class of 2016**
**Project Engineer, Blackhawk**
**Sikorsky, Lockheed Martin Corp.**
**Bachelor's Degree in Mechanical & Aeronautical Engineering, 2016**

I have harbored a keen interest in airplanes since I was a child born and raised in Lahore, Pakistan. We lived near the airport, and when a plane flew over our house, it was so close that it seemed as if I could touch it. I was so thrilled and excited that my parents began buying toy planes for me. Years later, I decided I wanted to become an aeronautical engineer, but due to my family's dire financial situation, I could not continue my education in aeronautics. Instead, I pursued a less expensive degree in Business Administration. After earning my Master's degree in Business Administration, I received the once-in-a-lifetime opportunity to come to America to pursue my lifelong goal.

Since aeronautical technology has always fascinated me, that goal was to become an aeronautical engineer. I particularly enjoyed studying mathematics and physics, and I knew that a graduate program in aeronautics would enable me to excel in these subjects. I believe success does not define us, but that we define success. To achieve my goal, I pursued a bachelor's degree in Mechanical and Aeronautical Engineering at Vaughn College of Aeronautics & Technology, and I graduated in 2016.

I believe that optimism, persistence and patience impel us towards success in life. Moreover, when our strong beliefs become deep convictions, we begin to achieve our goals. I had always dreamed of one day working for a major aeronautical institution, and for me that company was Sikorsky Lockheed Martin Corporation. My dream finally did come true, because I am now working as Project Engineer of Blackhawk (S70i) at Sikorsky Aircraft Corporation which is owned by Lockheed Martin.

I am so fortunate to have chosen and pursued my education at Vaughn College, because this college changed my whole life. I was especially fortunate to have found great mentors such as Dr. Rahemi and Professor Khalid who gave me the engineering knowledge which I now apply within the aerospace industry. I am also thankful to Dr. Sharon Devivo, President of Vaughn college, who maintains the standards of excellence within this institution.

> *"What you seek is seeking you in this Universe" by Rumi.*

# Industry Tour

1. **Engineering department Field trip to Maker Faire, Queens, NY**

On September 23, 2017, Drs. Hossein Rahemi, Margaret Ducharme, Shouling He, Prof. Manuel Jesus and several Vaughn engineering students traveled to the New York Hall of Science in Queens, New York to attend Maker Faire, a popular event promoting invention, creativity and engineering. Maker Fair event is a showcase for entrepreneurship and start-up businesses connected to hand-craftsmanship. This event also functions as an interactive gathering of tech enthusiasts, educators, hobbyists, engineers, authors, artists, students, and commercial exhibitors. These "makers" gather at the fair to show what they have made and to share what they have learned. With more than 750 Maker entries, the fair featured six stages and six attraction areas with many presentations and shows.



Our group visited a large number of additive manufacturing stands, including those of popular vendors such as FormLab 3D printer, DREMEL DIGILAB 3D printer and laser cutter, EPILOG Laser Fusion, Gianni Vincent 3D printer and leaser cutter, ShopBot CNC, and ROSTOCK Max 3D printer. The group also visited an aerial show demonstration of drones and robotics exhibiters.
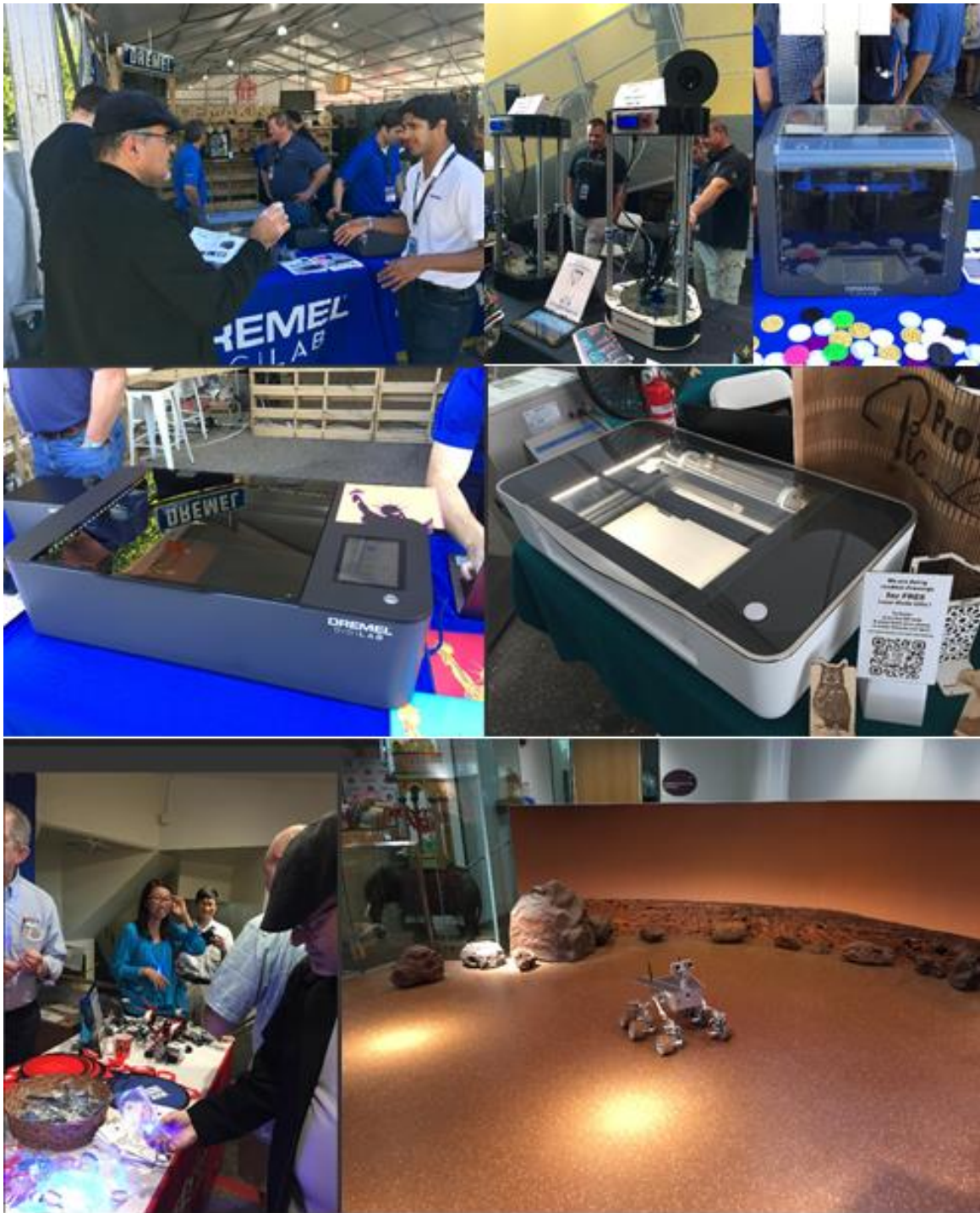
The field trip to the annual maker fair exhibition was a great opportunity for all of us and especially for our students to learn about current technology and advancement in the field of engineering and additive manufacturing.

2. **Vaughn Learning Community Field Trip to 2017 World Maker Fair**

The Vaughn Learning Community cohort of engineering students met on Sept. 23, 2017 at the NY Hall of Science in Flushing Meadows, Queens, NY for the 2017 World Maker Faire. This annual exhibition provides industry leaders and independent developers with the opportunity to showcase their inventions.

This field trip was organized within the engineering graphics, robotics design, and writing composition cluster of the learning community. The idea behind the organization of this activity was that students acquire greater interest in their topics of study and enhance their classroom learning when they have the opportunity to encounter and explore new science exhibits as a shared experience.

One exhibit which resulted in the students engaging with each other and with the exhibit in a positive and useful way was the Environmental Sustainability exhibit. This interactive invention projected images of scenic backdrops onto the floors and walls; these images were coordinated with sensors which interpreted human movements such as reaching out one's hand. The point of the exhibit was to reinforce the importance of the human role in sustaining the environment through planting seeds, cutting down old plants and watering new plantings.

Another exhibit with which the students interacted as a group was a water fountain piano in which depressing a piano key resulted in shooting streams of water within a pool. The water fountain shot out more powerful jets of water depending on how long a key or musical note was held down. This joint activity in which the students participated both challenged them to understand together how the fountain operated, and caused them to communicate with each other in order to produce a joint musical composition.

An additional educational goal of this trip was to encourage students to obtain as much information as possible to apply towards the design of their own robots this semester. All of the students were fascinated with the role of 3D printers in robot design. They are interested in using these printers to design robot parts using durable materials designed to withstand the forces these parts are expected to encounter.

The students also gravitated towards the Hall of Science booths at which they learned about the different ways to power robots, such as solar or wind power. They experimented with a kit for making circuits designed in patterns that were either solar powered or powered by electricity. They also learned new concepts in coding to make effective electrical components. All of these exhibits contributed to their overall understanding of concepts involved in the design of their robots this semester.

The students had the opportunity to discuss science in an informal atmosphere and to get to know their instructors and colleagues outside of the classroom. Students observed the contributions many private individuals continue to make to the world of science, and as a result of this group activity they seemed to develop a more positive attitude towards the creation of their own robots.

The ENG 110 learning objectives of teamwork and written communication were fulfilled through the individual reflection papers each student wrote about the Maker's Faire and through the collaborative report to which they all contributed.
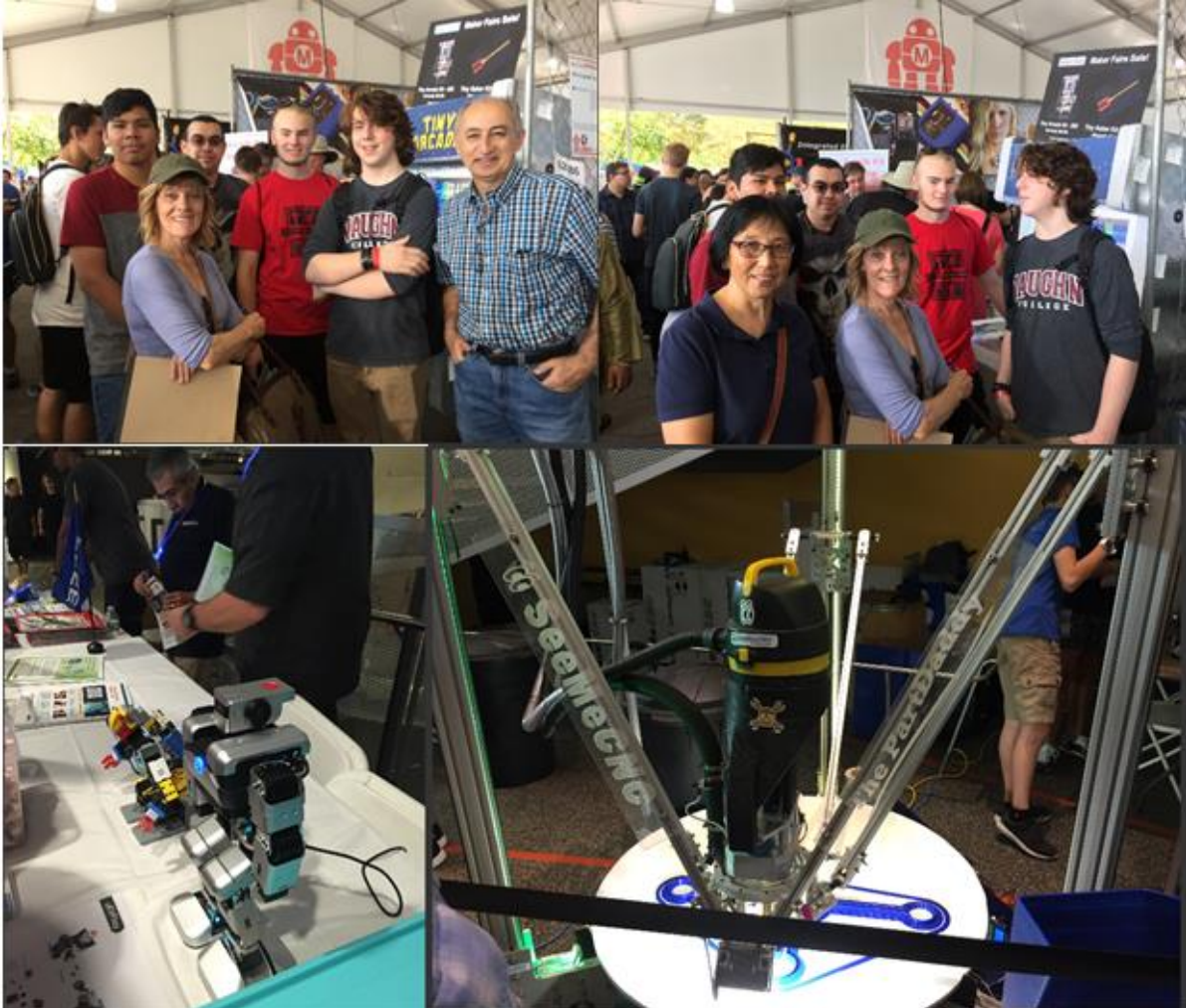
### 3. Field Trip to RCM Technologies, November 17, 2017

On Friday, November 17, 2017, eighteen Vaughn Engineering and Engineering Technology students (SWE, Robotics, and UAV clubs and NSF learning community), along with faculty mentors Dr. Paul Lavergne and Dr. Shouling He, visited the RCM Technologies in Shelton, Connecticut. The SWE club, in coordination with Career Services and the Engineering Technology department, organized this tour.

Upon arriving to the facility, the students were taken through the offices of RCMT and given a thorough presentation of the different engineering departments within the company. They also had the opportunity to meet Vaughn alumni and hear about their experiences in the field. Following this, the students were brought to RCM's Penthouse conference room where they were given the history of Sikorsky, and they had the opportunity to hear from some of the engineering managers about their industry experiences. The students also received information about the opportunities currently available for Vaughn's engineering students.



**Harry Pember, Vice President/ General Manager from RCM Technologies, talking with Vaughn students about the company and its many engineering opportunities**

The RCMT Engineering Managers continually mentioned their admiration of Vaughn students. According to Harry Pember, the Vice President/ General Manager of RCM Technologies, "Vaughn students enter the aviation industry with more technical knowledge than students from many other colleges and universities we've encountered. Their CATIA knowledge is what really makes them stand out from others." The RCM trip was extremely valuable to the students, because it gave them a first-hand look into the aerospace industry and their future opportunities within it. These industry visits allow our members to grow professionally and to gain valuable knowledge about different industries.

As the President of the Society of Women Engineers, Vaughn Chapter, I would like to thank Career Services and the Engineering Department for arranging this trip. Their continuous support of current and future SWE activities paves the road to an advantageous future for our members. SWE would also like to thank Dr. Paul Lavergne and Dr. Shouling He for taking time out of their day to serve as advisors for our trip. Their support for club activities and for student growth is what makes possible Vaughn College student success.

### 4. Manufacturing Day Field Trip to Curtiss-Wright Corporation Facilities

On Friday, December 1st, 2017, eleven Engineering and Engineering Technology students, along with faculty member Jonathan Sypeck and Vaughn College Internship Director Sean Manning, attended an industry tour at Curtiss-Wright Corporation's Target Rock facilities in Farmingdale, NY. This tour was arranged by Ms. Jessica Caron, Director of Vaughn College Career Services, and Mr. Manning. These students and staff members visited the Curtiss-Wright manufacturing facility, which produces different types of valve and pressure systems with advanced CNC milling machines used in the defense industry as well as in the home building industry. During the presentation and discussion period, Curtiss-Wright team engineers explained in detail how various valve-systems are designed, manufactured, and evaluated. Specifically, they showcased the software they use to create various mock-ups, and the evolution the valves take from design to manufacturing. This tour reinforced in our students an appreciation for their engineering education, especially their Computer Aided Design and Finite Element Analysis courses, as they were brought to understand how their classroom instruction translates into the design and analysis process of an industrial product.



**Manufacturing Day Industry Tour to Curtiss-Wright Corporation**

## 5. Field Trip to Thales Avionics

On Friday, February 2$^{nd}$, 2018, Prof. Minhas accompanied a group of students from the Engineering and Technology department to Thales Avionics Services Worldwide, a division of Thales Group. Thales Avionics Services Worldwide Americas, part of the global footprint of Thales avionics support bases and facilities, provides support activity for flight avionics equipment. The group met with Mr. Richard Flocco, Vice President of Operations at Thales ASW, who gave them a detailed tour of the entire facility and a description of different departments and their operations. Mr. Flocco stated that as an Original Equipment Manufacturer Thales has extensive and recognized expertise in providing avionics services for every type of aircraft - from large airliners to business jets and helicopters, as well as flexible services tailored to thousands of customers. This facility also features aftermarket support for critical spare parts needed for air carriers.

While touring the maintenance operation floor, students observed how troubleshooting and repair

activities are conducted. Thales features a range of automatic and semi-automatic test equipment used for avionics testing, troubleshooting and fault isolation. During a Q&A, Mr. Flocco stated that it is paramount for college graduates within the field to understand the many different aspects of an MRO and to have both a solid understanding of how avionic systems operate, as well as a basic knowledge of circuits. He emphasized how important the acquisition of an avionics troubleshooting philosophy is among graduates, rather than their dependence upon particular test equipment.

Mr. Flocco was pleased to know that students at Vaughn College acquire all of these skills through several courses in the EET-Avionics program. In the Internet of Things (IoT) course, for example, the study of microprocessors has direct application to predictive maintenance systems developed and introduced into future avionics systems. As a result of learning about such courses, Thales ASW is now contemplating an internship collaboration with Vaughn College.

During lunch, students were introduced to team leaders from other departments for a detailed Q&A session. Professor Minhaus summarized the events of the day "I am particularly glad to know that the skillset students acquire through courses in the EET-Avionics curriculum corresponds to the needs of the industry. This is due to our team of dedicated and knowledgeable professors who continue to evolve the course material and lab exercises based on industry feedback."

64

## 6. Field Trip to Brookhaven National Laboratory – Friday, March 16, 2018



On Friday, March 16, 2018, Mr. Rodney Dash, Associate Professor of Department of Arts and Science, Jessica Caron, Director of Career Services, Dr. Sundari Ramabhotla, Assistant Professor of Engineering and Technology at Vaughn College of Aeronautics and Engineering, and 13 students from Vaughn College's Engineering and Technology Department visited the Brookhaven National Laboratory (BNL) in Upton, New York as a part of Learning Community. The tour was organized by Tara Shiels, Stakeholder Relations Office of Brookhaven National Laboratory and included visits to two facilities in the lab.

A welcome and brief overview of BNL Escort was given by Tara Shiels of Brookhaven National Laboratory. The first trip of the tour, led by Bernie Kosciuk of the BNL facility, was to The National Synchrotron Light Source II (NSLS-II), one of the most advanced synchrotron facilities in the world. The lab provides an opportunity to study the material properties and functions with nanoscale resolution and exquisite sensitivity. It has high leading capabilities for X-ray imaging and high resolution to analyze the energy. Students from academia and users from the industry are allowed to visit this facility in order to provide them with an opportunity to work on new scientific discoveries and technical innovations in the area of energy security, the environment, and human health.

The next trip of the tour, led by Christopher Bruno and Keith Radich of the facility, was to Chilled Water Plant at BNL. This lab provides water conservation techniques and good management practices. The lab contains efficient utilized water processes along with low consumption plumbing fixtures in order to reduce water consumption by 2%. The water here is supplied by 5 groundwater wells and mainly used for process cooling at BNL's scientific facilities. Ten percent of the facility water is used for human consumption and sanitation. The 80% utilized lab water is returned to the underground and recharged at the nearest underground water quality well.

The Vaughn faculty, students and staff expressed their appreciation to Brookhaven National Laboratory (BNL) in Upton, New York for giving us an opportunity to visit the facilities at BNL.
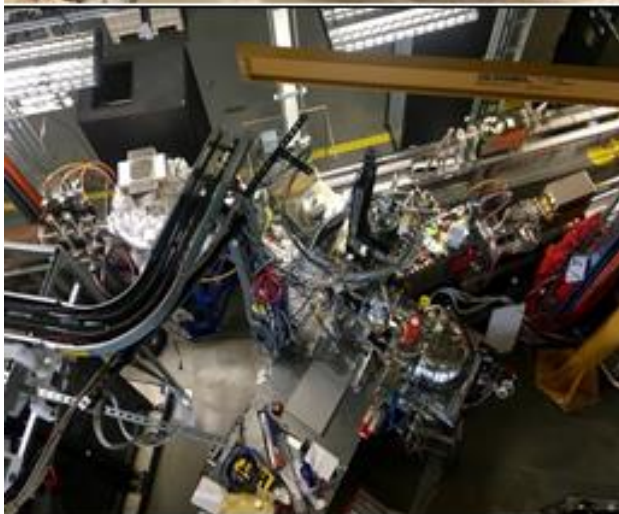
**Industry Connection Seminar**

Tuesday, October 10, 2017
11 am – 12 pm
Room E103

**Topic:** Aviation Engine Trends — Transitioning an engine from high power and large fuel consumption to a more efficient engine

Presenter: Mr. Dominic Visciotti, Team Leader Assembly Engineering at CYIENT

Mr. Dominick Visciotti is an alumnus of the Vaughn College of Aeronautics and Technology, and he has spent several years in various technical and leadership roles in the engineering and aerospace industries. Currently, Mr. Visciotti is serving as a Team Leader Assembly Engineering at CYIET. He addressed students on engine efficiency and modern improvements with a presentation entitled "Aviation Engine and Engineering Trends," and he offered advice on the importance of a work ethic and on life after college.

In this seminar, Mr. Visciotti talked about some of his professional experiences, and he discussed some of the projects he is currently involved with at CYIENT. He provided insight into Aviation Engine trends such as transitioning engines from being high powered with large fuel consumption to more efficient engines with the same power output. In this seminar Mr. Visciotti emphasized the following items:

1. Today's Engines and Their Efficiency: Reduction in fuel consumption 15% by 2015 and 20% by 2020, emissions reduction by 50%, and noise reduction by 75% (from 85 db to 83.3 db)
2. Career opportunity in aerospace and what employers in today's marketplace are looking for. He also talked about employer expectation and he addressed the need for skills such as determination, imagination, communication, teamwork, and discipline as building blocks for a successful career.

His presentation was followed with a 15 minute open discussion session.

# Industry Connection Seminar

Tuesday, November 7, 2017
11 a.m. to 12 p.m., Rooms 101, 103



**Presenter:** Mr. Manny Santana, Quality Assurance with the Department of Defense
**Topic:** Quality Management Systems (QMS)

Mr. Manny Santana, a 2013 Vaughn College graduate and Quality Assurance employee with the Department of Defense acquisition team, addressed the Vaughn community on Tuesday November 7, 2017 as part of the College's Industry Connection Seminar series. Mr. Santana's technical career began with the US Navy by completing a BS degree in professional aeronautics. While studying at Vaughn College, he started a full-time position with Arkwin Industries as an Aircraft Test Engineer who tested Aircraft Hydraulic and Fuel System components such as Actuators, Reservoirs, pumps, etc. After graduating from Vaughn College, Mr. Santana obtained a position with the department of defense in the Quality Assurance division.

In this seminar, Mr. Santana talked about quality management systems, the importance of professional development, the definition and processes of international organization for standardization (ISO), and quality management principles. Mr. Santana discussed the importance of evidence based decision-making, and the process approach to critical problem solving. At the conclusion of the presentation, the discussion was opened up for questions from students and faculty.



68

# Industry Connection Seminar

Thursday, November 9, 2017
11 a.m. to 12 p.m., Rooms E101, 103

**Presenter:** Mr. Matthew Pearce, NASA Education Programs Specialist
**Topic:** NASA's Internships Program and other career opportunities

Mr. Matthew Pearce, NASA Education Programs Specialist, addressed the Vaughn community on November 9 as part of the College's Industry Connection Seminar series. In this seminar Mr. Pearce talked about various NASA's internships, fellowship programs, and other career opportunities.

Along with recounting his time with the Goddard Institute of Space Studies, he went over internship options for current students. "Before this, I've never loved getting up and going to work" said Pearce. "At NASA, there's a great culture that really inspires and challenges you. You're lucky that Vaughn pushes you in a similar way."

Mr. Pearce also spoke on current work in the NASA climate change research initiative (CCRI) and its yearlong interdisciplinary vertical STEM education research. Students filled room E101/E103 to ask questions and to learn about NASA's fellowship and scholarship opportunities. He encouraged Vaughn's engineering and engineering technology students to apply for those opportunities to gain NASA's valuable career-building experiences.

Mr. Pearce's presentation was followed by 30 minutes of open discussion with students, as well as a visit to the UAV and Robotics room; he was very happy to learn about Vaughn students' active involvement, accomplishments, and success in the STEM fields.

**Industry Connection Seminar**
Tuesday, November 14, 2017
11am - 12pm, Room E101
Topic: Performance-Based Navigation - PBN
Presenter: Mr. Marcos Fernandez, Aviation Safety Management System Consultant & Adjunct
Professor at Vaughn College

In this seminar, Mr. Fernandez gave an introduction to one of the main pillars that will support the future air navigation system known as Performance Based Navigation (PBN). PBN concept has been developed by the International Civil Aviation Organization (ICAO) in order to harmonize area navigation and required navigational performance (RNP) specifications. PBN enables the introduction of new navigation technology in a faster and more efficient way.

Mr. Fernandez' presentation focused on PBN as an advanced, satellite-enabled form of air navigation in the National Airspace System (NAS) that creates precise 3-D flight paths. He explained how FAA has published more than 9,000 PBN procedures and routes, including hundreds to enhance air traffic control and flight operations at airports in large cities.

Mr. Fernandez emphasized how if an aircraft relies on satellite positioning with GPS or Wide Area Augmentation System (WAAS), its avionics can navigate a flight path with much greater precision and accuracy than with legacy navigational systems. PBN procedures require various avionics capabilities, depending on the level of navigation precision involved. Because of mixed equipage, not all aircraft can fly the most-demanding types of PBN procedures. New aircraft usually have the latest avionics while older aircraft have a mix of avionics of various ages and capabilities. Replacing aging equipment can prove too expensive for some aircraft operators and may lead to an aircraft being retired. In other cases, an aircraft's existing equipment may be adequate for the types of flight operations planned.

"The benefits include lower fuel consumption and emissions as well as time savings," said Fernandez. "Whatever the future brings, PBN will be a key enabler for the future of air navigation."

**Industry Connection Seminar**
Thursday, November 16, 2017
11 am – 12 pm
Room E101 & E103

Topic: Taming The Advanced Scoring Platform (ASP) a research and development tool for Mechanical Scoring & Separation of glass
Presenter: Mr. Michael Joseph, Sr. Project Engineer with Corning Incorporated

Mr. Michael Joseph, a 1982 Vaughn College graduate and senior project engineer of the manufacturing, technology and engineering division for Corning Incorporated addressed the Vaughn community on November 16, 2017, as part of the College's Industry Connection Seminar series.

In this seminar, Mr. Joseph talked about his research experience in cutting high strength glasses and he gave a presentation on Advanced Scoring Platform (ASD) capabilities. He presented his background to students, and then he went on to describe how Corning takes part in manufacturing both catalytic converters and gorilla glass used in iPhone and Samsung phones. He gave projections on the introduction of gorilla glass technology into future models of car windows, in which the user can manually adjust the tint opacity.

Mr. Joseph discussed mechanical scoring and separation of glass, and he provided an overview of the history, development of tools, and methods of glass cutting. Also, he discussed internship and job opportunities with Corning, and he encouraged Vaughn's engineering students to apply for career-building opportunities with this company.

## Industry Connection Seminar
Tuesday, January 29, 2018
12 pm – 1 pm
Room W155A

**THALES**
Together • Safer • Everywhere

Topic: Avionics Innovation Initiatives

Presenter: Dr. Denis Bonnet, Chief Innovation Officer of Thales Avionics

Dr. Bonnet, a Chief Innovation Officer at Thales Avionics, addressed the Vaughn community on January 29 as part of the College's Industry Connection Seminar series. He opened the session with a description of his educational background in artificial intelligence as a graduate Ph.D. student in France. He then discussed his professional experiences as a chief innovation officer at Thales Avionics. His presentation covered topics related to Thales avionics equipment, hardware, devices, connectivity, his leadership of current innovation processes for the avionics GBU, and other relevant items.

Dr. Bonnet has been with Thales/Thales Avionics for 15 years. He currently oversees innovation processes for the Avionics GBU which include: Flight avionics, in-flight entertainment, electrical systems, training & simulation, and medical devices. He has also led the company's efforts in the areas of Cockpit Innovation, Human Engineering for the Cockpit Center of Competence, Safety, Software Engineering and Project Management.

His presentation was followed with a 15 minute open discussion session.

# Vaughn's 3rd Annual Manufacturing Day, Oct 27th 2017, 10 am to 2 pm



The Engineering and Technology department hosted its 3rd Annual Manufacturing Day conference on Friday October 27th to celebrate national manufacturing day. Vaughn College invited four industry leaders and two faculty members to address invited guests and the Vaughn community about manufacturing innovation in the area of additive manufacturing, cyber physical systems, 3D printing, composites, CNC machining and automation in manufacturing.

Mr. Albert Bunshaft, Senior Vice President of Dassault Systèmes, talked about "Changing Dynamics for Design and Manufacturing Companies in the 21st Century". He expressed Dassault Systemes' findings on recent advancements within the manufacturing industry and how these changing dynamics shape ongoing procedures. Bunshaft also noted that mindset and adaptability are important qualities for manufacturers to have in staying current within the industry. He discussed how graduates with hands-on skills in communication, problem solving, and teamwork are greatly needed for the advancement of today's growing manufacturing industries. After Dr. Rahemi thanked Mr. Bunshaft for his inspiring presentation, Dr. Rahemi went on to point out that, in the last two years, the engineering and technology department has adapted to advancements in today's technology by fostering creativity, innovation, and hands-on learning within all programs. As a result, many of our students are engaged in professional and scholarly activities, such as conference presentations and technical competitions.

The second presenter, Mr. Oliver Scheel, President of US Didactic, talked about the Integration of Advanced Manufacturing into Cyber Physical Systems. His presentation covered the connection of physical components, hardware systems, and enterprise level software with the 'Internet of Things.' He also explained which educational skills are needed in order to participate and to succeed in this fast-growing segment of the industry.

The third presenter, Mr. Dominick Visciotti, team leader assembly engineering at Cyient, talked about the "Outsource Companies Moving from the Service to Solution." He talked about how his company provides outsource engineering for many other aerospace and manufacturing industries. He also talked about manufacturing employment opportunities in the aerospace industry and the market and employer expectations of new graduates. He emphasized the need for skills such as determination, imagination, communication, teamwork, and discipline in order to build a successful career path.

The forth presenter, Mr. Hal M Staniloff, A UAS remote pilot and owner of Estate Aerial Inc., talked about "Overview of UAS Industry - History, Regulation, and applications." He provided a comprehensive overview of the current state of small Unmanned Aerial Systems (UAS). Mr. Staniloff presented some basic definitions of UAS is and he outlined in detail what is and what is not considered a 'Drone'. Mr. Staniloff discussed the many applications emerging now for small UAS systems, the regulations the FAA is struggling to roll out, and he described some of the newer technologies available. Mr. Staniloff reminded the audience of concerns created by the 'rogue' operator, who is often unaware of regulations and who may fly drones unsafely in

74

violation of basic aerial restrictions. He wrapped up his talk with an active discussion followed by lively questions and answers.



**Morning Session of Manufacturing Day Conference – Presentation of Industry Leaders**

In the afternoon session, Dr. Rahemi, Prof. Manuel Jesus, and Dr. Budhoo, talked about the development process of stackable manufacturing certificate programs, as well as the

75

development of a new advanced manufacturing concentration as part of the current MET program. Prof. Jesus' presentation addressed the CAD Subtractive and Additive manufacturing certificate program and laboratory development related to software, hardware, 3D scanning, CNC lathe and other equipment that can support implementation of both additive manufacturing and CNC machining certificate programs. Dr. Budhoo talked about courses offered in the composite design and manufacturing certificate program, as well as development of laboratory equipment that provides students with the hands-on skills current with today's technology in the composite manufacturing industry. Dr. Rahemi mentioned that the proposal for the composite manufacturing certificate program has been submitted for approval to the NYSED, and the department is also in the process of completing and submitting a proposal for its additive manufacturing certificate program to the NYSED by mid-November. He discussed how the establishment of those stackable certificate programs with the state-of-the-art laboratories in 3D printing, CNC machining & programming, composite manufacturing & non-destructive testing, and the UAS center will not only provide our engineering and engineering technology students with hands-on manufacturing skills but will also facilitate the development of the advanced manufacturing program that is supported by the Department of Education federal fund as part of Title III, Part F, HSI-STEM and Articulation grant (Award#P031C160021).



**Faculty presentation to invited guests and Vaughn community about composite manufacturing and additive manufacturing certificate programs as well as about the development process for the advanced manufacturing program**

**STEM Outreach Workshops**

In a parallel session, from 11 am to 2:00 pm, Vaughn's UAV and Robotics clubs organized and hosted workshops on building a drone, robotics design, and autonomous programming for the high school students from Freeport, Bayside, Garden City, and South Country school districts, as well as from The Wheatley School and Thomas Edison high schools. The UAV club workshop consisted of mechanical, electrical, and programming parts to simulate bi-directional control of a small dc motor. Students learned the basic principles of C++ programming with the Arduino IDE. Additionally, students learned to work with electrical components such as a potentiometer, h-bridge motor controller, diodes etc. and they assembled and programmed the circuits in two sessions. Overall, students had the opportunity to experience the different disciplines of engineering. The robotics club conducted a workshop related to robotic design using SolidWorks. The club also instructed students in the structural design process necessary for the creation of a robot that will perform quickly and accurately during a competition. We are grateful for the support provided by the Department of Education federal fund as part of Title III, Part F, HSI-STEM and Articulation grant (Award#P031C160021).



**UAV and Robotics Workshops Session**

## Vaughn's International Drone Day,
## May 6, 2017 10 am to 3 pm

On Saturday May 6, 2017, the engineering and technology department hosted several drone workshops such as CAD Modeling of Quadcopters, Build a Drone, and Programming with Python in order to celebrate International Drone Day. The event allowed visitors and students to design, build, and test their own drones in the netted flying arena of the college hangar.

These workshops, organized by the engineering and technology department and the Unmanned Aerial Vehicle (UAV) club, were coordinated in an effort to raise awareness of these flying devices. The CAD workshop provided participants with insight into 3D design and the modeling of Quadcopters. The Build a Drone workshop introduced participants to the building and manufacturing process of flying robots. Finally, the Python workshop introduced participants to programming and coding with Python.

In the afternoon, the UAV club organized a drone practice flying session, and the participants were able to fly their drones in the Vaughn hangar flying arena. The participants for the workshops and drone flying session were invited guests and students from Bronx Science, Robert F. Kennedy Community, and Thomas Edison high schools. Vaughn's UAV team flew their drone, which had been selected by the American Helicopter Society (AHS) as a finalist for both manual and the autonomous categories for the 2017 AHS Micro Air Vehicle (MAV) competition. This MAV competition will take place on May 8, 2017 in in Dallas Fort Worth Convention Center. This is a tough and challenging competition in which only the top teams with supporting documentation and videos that prove their drones can complete the tasks were invited as finalists to compete in the Annual American Helicopter Society Micro Air Vehicle (MAV) competition. Besides Vaughn's team, five other schools (Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University) were also selected as finalists in the AHS-MAV competition. Vaughn's UAV team provided a brief presentation of their drone design, which employed 3D printing parts and autonomous programming, to the participants of Vaughn's International Drone Day.

**Workshops: CAD Modeling of Quadcopters, Build a Drone, Python Programming, and Drone Panel Discussion - Vaughn's International Drone Day, May 6 2017**

**Vaughn's UAV team participated in the American Helicopter Society Micro Air Vehicle (MAV) competition, May 8, 2017**

Vaughn's UAV team project was selected as one of the finalists along with Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University to participate in the 5th annual Micro Air Vehicle (MAV) student challenge competition at Dallas Fort Worth Convention Center on May 8, 2017. Vaughn's UAV team developed two drones to compete in both manual and autonomous categories and the following is a list of the teams (alphabetical order) which were selected by AHS as finalists in this challenging MAV competition.

**Autonomous Category Finalists**
- Georgia Tech
- North Dakota State University
- Penn State
- Vaughn College

Wait List #1: University of MD
Wait List #2: NC A&T

**Manual Category Finalists:**
- Georgia Tech
- University of MD
- Vaughn College

Wait List #1: Concordia

The drone for this competition should be designed to perform vertical takeoff & landing (VTOL) with onboard flight-stabilization and camera. The drone's weight should be less than 500 grams and should have delivery, pickup, obstacle avoidance, and hover/landing capabilities. The drone's design should be lightweight while not sacrificing its autonomous, computational and flying control.

For both autonomous and manual, a drone with a package will take off from a base station, move around an obstacle and drop off the package on a pre-identified delivery station. The drone then would takeoff from the delivery station and land on the pickup station to pick up a 2nd package and then finally fly back to the base station to land and deliver that package. Among all participating teams, only teams from the University of Maryland and Vaughn College were able to complete the remotely-operated tasks within the 10 minute time limit. As the 2017 winners of the Micro Air Vehicle competition, judges from industry and academia selected the team from the University of Maryland in the first place with a $1,500 check award and the team from Vaughn College was awarded second place with a $1,000 check award. Seven members of the Vaughn College UAV team (Wassem Hussain, Bobby Tang, Utsav Shah, Andrew Aquino, Sayhat Karca, Sagufta Kapadia, Syed Misbahuddin) were part of 2017 AHS-MAV student challenge competition.
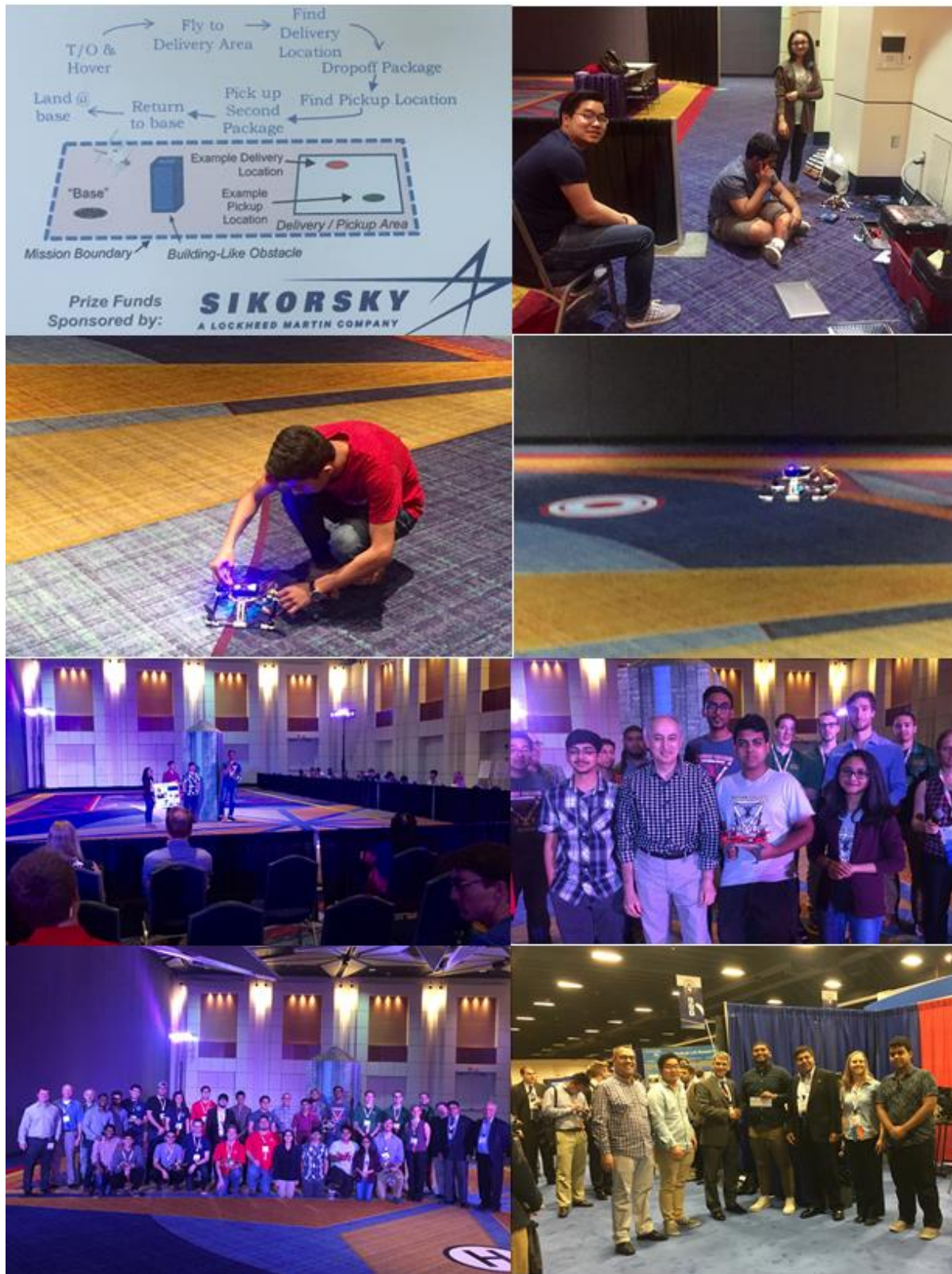
**5th annual American Helicopter Society Micro Air Vehicle (MAV) Student Challenge Competition, May 8, 2017 – Vaughn's UAV team finished 2nd place with $1000 Prize.**

**Vaughn's engineering students and faculty presented their research projects at 2017 ASEE Annual Conference and Exposition.**

From June 25 through June 28 Vaughn faculty and students attended the American Society for Engineering and Education (ASEE) 124th annual conference in Columbus, Ohio.

On Tuesday, June 27, Vaughn students Waqas Latif, Milana Natanova, and Richa Bagalkotkar presented their capstone research project on "**Volumetric Flow Visualization using CWLaser and Scanning Mirrors.**" during a maker event Conference Session. This presentation detailed the design of a new and improved volumetric flow visualization system using continuous wave laser and scanning mirrors. This system has a uniform light intensity with the capability of producing multi-layer laser sheets to create a 3D image of the flow that spreads over a large volume. Compared to the existing devices used in the aviation and space technology industries, such as the Particle Image Velocimeter and the NFAC Long–Range Laser Velocimeter (LRLV), the light intensity of each sheet produced by the Volumetric Flow Visualization System is uniformly distributed, and the strength of the intensity remains unchanged. This project was partially sponsored by Maxon Precision Motors, Inc., a leading company in building micro-motors used in humanoid robots, commercial aircrafts, camera lenses, race cars, cardiac pumps and other high precision industrial applications.
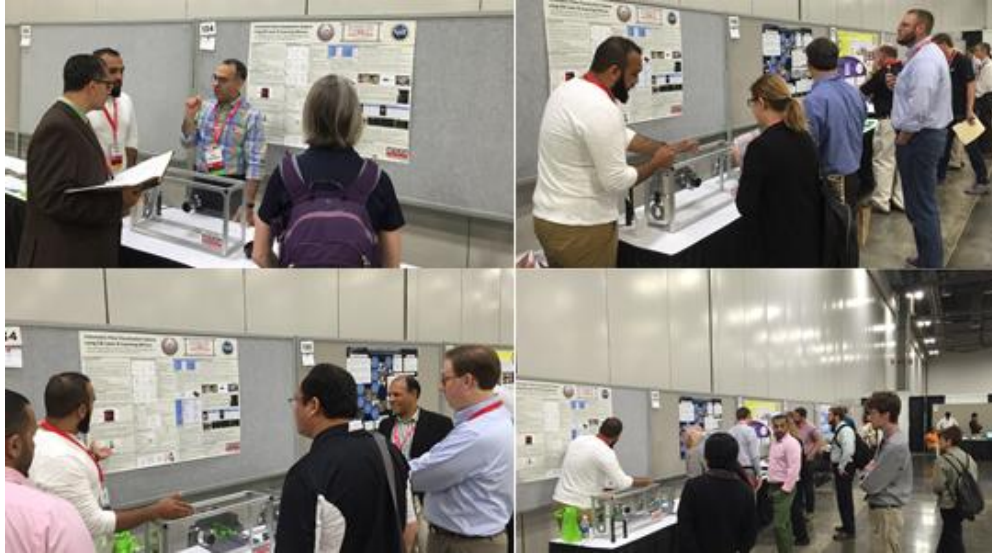
Among twenty participating teams, Vaughn's student paper won the "Innovation Award" of the manufacturing division's "Make It" session of the conference.
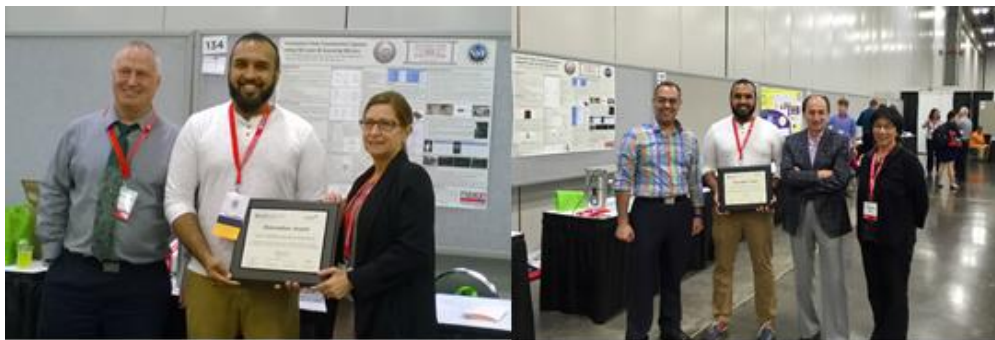
Vaughn faculty members Dr. Hossein Rahemi, Engineering and Technology department chair, Dr. Margaret Ducharme, Art and Science department chair, and Dr. Shouling He, Mechatronic Engineering program coordinator participated in the 2017 ASEE annual conference and presented their paper "Summer Engineering Experience (SEE) Program to Prepare Freshman Students for Engineering Studies." The paper and their presentation detailed the development, implementation, and learning outcomes assessment process of the SEE program. The main objectives of the SEE program can be categorized as follows:

1. Introducing freshman students to the topics that can enhance their hands-on, computational, programming, and problem solving skills.
2. Enhancing their interest in STEM related fields and preparing them for the core courses within engineering and engineering technology disciplines.
3. Engaging them to the real-world engineering workshops that instill awareness of continual technological changes and the importance of lifelong learning in meeting future professional challenges.
4. Producing a pool of talented students that can excel in their field of study and be successful in their career path.

This paper addressed topics that were introduced through the SEE program, a process that helped to improve students' computational, programming, hands-on, technical writing and group presentation skills. Furthermore, this paper addressed a process to monitor and assess SEE student performance through core courses, and student involvement in out-of-class professional activities in comparison with those who did not participate in the SEE program. We are thankful to the Department of Education federal grant (Title III, Part F, HSI-STEM and Articulation grant, Award#P031C160021) which provided necessary funding support to implement the SEE program.

**Vaughn's Engineering Faculty and Students Participated in LACCEI2017 Conference; Vaughn's Students Take Second Place at LACCEI 2017 Paper Competition**

From July 18-21, Vaughn's engineering and technology students, along with department faculty, attended the LACCEI 2017 Conference in Boca Raton, Florida. Four Vaughn student team research papers were accepted for presentation and publication in the LACCEI2017 international conference; one out of four submitted papers was accepted for the student paper session competition, and all four were accepted for the poster session of LACCEI2017.

From 11 am to 1 pm on Thursday July 20, one of our student team papers was presented to the international conference audience during the student paper competition session of LACCEI2017. The "**Innovative Drone Design for the AHS Micro Air Vehicle Competition**" by Bobby Tang and Utsav Shah was a finalist for the student paper session competition. Their drone project was designed, developed and completed during spring 2017 in preparation for the American Helicopter Society International 2017 Micro Air Vehicle Student Challenge on May 8, 2017. This paper outlines the project idea of creating two micro aerial vehicles weighing less than 500 grams and sized less than 450 millimeters in any dimension. The quadcopters designed in this project have two different types of package delivery, pickup, obstacle avoidance, and hover/landing capabilities with autonomous and manual control. Out of ten finalist papers, Vaughn's student paper received the 2nd place award in this session.



**LACCEI2017 Student Paper Session Competition**

**LACCEI2017 Poster Competition**

From 2 pm to 4 pm on July 20, a total of 40 posters were presented during the poster session of the LACCEI 2017, including four of Vaughn's student team posters; **1) Innovative Drone Design for the AHS Micro Air Vehicle Competition** by Bobby Tang and Utsav Shah, **2) Self-Designed Drone as A platform for Engineering Education**, by Andrew Aquino, Bobby Tang, Utsav Shaha, Daniel Khodos, **3) Anti-Spill Cup by** Monica Vanterpool and Dimitri Papazoglou, and **4) The Jungle: An Aeroponic System for Individual Urban Agricultural Needs**, by Gonzalo Forero, William Mayorga, and Dylan Neary. Among all participating teams, Vaughn's **Anti-Spill Cup** and **Innovative Drone Design for the AHS Micro Air Vehicle Competition** posters received many compliments from the audience.

Bobby Tang and Utsav Shah, Vaughn's Mechatronic Engineering students, received the second place award in the student paper competition from president of LACCEI, Dr. Jose Carlos.

**2017 Society of Hispanic Professional Engineers (SHPE) National Conference, Kansas City, Missouri, Nov. 1-4, 2017**

A group of 10 engineering students from Vaughn College attended the 2017 Society of Hispanic Professional Engineers (SHPE) Conference in Kansas City, Missouri from November 1 to November 4, 2017. The underlying purpose of the conference was to help them sharpen their leadership skills by participating in design competitions and professional development workshops and to expose them to the diverse career opportunities awaiting them in the STEM fields.

Vaughn's future engineers eagerly participated in a variety of challenging competitions, presented technical papers, and connected with other engineering students and accomplished professionals from all across the United States.

**Extreme Engineering Challenge (Wednesday and Thursday):**

A group of Vaughn students participated in the Extreme Engineering Challenge, a non-stop, 24-hour competition in which teams' intellect, creativity, imagination, and business skills were tested in order to experience a real engineering process.

Vaughn students Hector Sabillon, Darwing Espinal and David Adegbesan were chosen from a pool of 350 candidates from engineering schools across the United States to be members of one of the teams that would participate in a competition to develop and promote a product in a race against time, talent, and creativity. Darwing, Hector and David, along with their team members, were placed in a structured environment that simulated an accelerated working scenario with deadlines, presentations, reviews, and obstacles in order to build awareness of and enhance the skills required to meet the demands of extreme engineering.

At the conclusion of the challenge, Vaughn student, Darwing Espinal's group, whose design topic was related to an active suspension system, received third place in the competition.

89

**Hospitality Suits (Career Fair):**

While attending the SHPE Conference, the Vaughn College students visited a number of hospitality suites where they had a rare opportunity to meet one-on-one with recruiters from a variety of major corporations, including Toyota, Boeing, Texas Instruments, Aerotek, Facebook, General Motors, and Northrop Grumman.

Among the students in attendance at the SHPE National Conference were Katherine Inamagua, Jessica Jimenez, Lovedeep Kaur, and David Adegbesan, all of whom are expected to be graduating in May of 2018. Lovedeep received around seven on-site interviews and three Full Time Job offers from companies such as Northrop Grumman, General Dynamics and John Deere as an Electrical Engineer. She is currently considering Joining Lockheed Martin's Electrical Engineering team in Connecticut after graduation in May of 2018. Jessica received five on-site interviews and a job offer from Raytheon as a Mechanical Engineer. David is currently awaiting offers from Rockwell Collins. Katherine Inamagua had multiple interviews and she received an offer from the NSA, as well as from the FAA, after she graduates.

Robert Escobar, Hector Sabillon, Darwing Espinal, Nicolas Ceballos, Jairo Chauca, and Lennin Luna will be graduating in May of 2019, and all received multiple on-site interviews. Robert is currently waiting to begin an internship as a Manufacturing Engineer at Caterpillar's Solar Turbines Company in the summer of 2018. Hector was recently flown to Iowa for an interview at John Deere. Darwing, received a Co-op offer from BAE Systems and he is currently awaiting an offer from Boeing and General Dynamics for a Summer 2018 internship. Nicolas received an internship offer from DOW Chemicals.

**Workshops**

In addition, the students attended a variety of workshops, including leadership development, academic excellence, cultural awareness, professional skills, career development, and technology. They learned about the skills needed to define a leader in the engineering industry. They were also given helpful tips on how to successfully navigate the academic arena in their engineering careers.

As part of the technology workshops, students were given the opportunity to explore careers related to their majors and to discuss what personal contributions they can make towards innovative and effective solutions to help solve today's problems in the engineering industry.

Some of the students took advantage of the professional skills workshops where they were provided with hands-on knowledge and personal experience anecdotes that will aid in the development of their soft skills, as well as assist them in becoming effective communicators and successful leaders.



The workshops were sponsored by leading engineering companies, including Facebook, Google, Boeing, Northrop-Grumman, and Lockheed Martin. All of the corporations provided the students with numerous networking opportunities.

Students participated in a variety of workshops, including leadership development, academic



excellence, cultural awareness, professional skills, career development, and technology. In addition, they learned about the skills needed to define a leader in a corporate setting. They were also given helpful tips on how to successfully navigate the academic arena in their chosen engineering careers. As part of the workshops, the students explored engineering careers related to their specific majors. They were extremely excited about the many prospects that will be available to them in the engineering field once their formal education has been completed.

Students listened eagerly to professionals who explained to them how they, as engineers, would be challenged to make major and innovative contributions to global markets.



91

**Training course at Abaris Training facility Reno, Nevada**
**Advanced Composite Structures: Fabrication & Damage Repair-Phase 1**

From May 15-19, 2017, Dr. Budhoo attended a five-day training course on "Advanced Composite Structures: Fabrication & Damage Repair-Phase 1" at Abaris training facility in Reno, Nevada. This course consisted of both theoretical and practical presentations; the hands-on exercises involved work with prepreg carbon fiber unidirectional tape to explore the effects of orientation, "balance," and "symmetry," in a laminate. Hands-on exercises also included work with dry glass fabric and liquid epoxy resin in an exercise designed to teach fundamental vacuum bagging, bleeder & breather concepts. Experience was also gained while working with prepreg glass and aramid fibers and Nomex honeycomb and polyurethane foam core materials, while making sandwich panel. Finally, basic repair methods and techniques were presented along with performing a "wet layup" repair in the lab.

Implementation of this course into the Vaughn College curriculum will provide students with a hands-on experience as well as prepare them for a career in the manufacturing industry.



Class Photo for Advanced Composite Structures: Fabrication & Damage Repair course

**CATIA Generative Shape Design surfacing workshop**

From June 7-9, 2017 Prof. Manuel Jesus participated in a CATIA Generative Shape Design surfacing workshop. Surface modeling in CATIA was covered extensively as a method to further develop shapes for 3D printing and manufacturing. Class A surfacing and curvature continuity was discussed as a method to manage the properties of 3D surfaces during part development. Underlying concepts of Nurbs vs. Cubic data structure were discussed; however, CATIA modeling tools were used as a method to guard CAD technicians from equations, so they can focus on a more parametric approach to part development. Many modeling functions were explored such as: curve creation tools and surfaces consisting of revolves, offset, blends, lofts, sweeps, and variable surface fillets. Surface editing functions such as trims, projections, and drafts were explored, and conversion to solids was presented as a final step.

There are a few reasons to include surface modeling into a CAD curriculum. Surfaces can help students rebuild areas of imported and broken features in solid models. The problematic faces can be deleted and reconstructed with surface modeling tools. Complex shapes can be constructed that are simply not possible with solid model features. Surface models are developed for use in the design of car bodies, aerospace parts, and consumer products. The Generative Shape Design Workbench allows designers to focus on both design aesthetics in addition to engineering of parts. Solid modeling tasks benefit from surface modeling, since surfaces are used as reference geometry in the creation and modification of solid model features.

Surface modeling isn't really a replacement for solid modeling, but there are times when solid modeling simply can't achieve the desired shape. Teaching students surface modeling as part of a CAD curriculum insures students are on course to mastering 3D modeling. Conversations with students in the UAV and Robotics clubs revealed an eagerness to learn more about 3d modeling; specifically aircraft shape styling. The knowledge acquired in the CATIA surface modeling workshop will be incorporated into CDE 375: Computer Graphics for Engineers. This course already offers surface modeling content with Solid Works, but course content will be expanded to cover CAD tasks outside the scope of what is possible in CDE 385: CATIA Fundamentals. Students will be able to use these skills in club activities, degree projects, and courses related to aircraft design.

**Training course at Abaris Training facility Reno, Nevada**
**Non-Destructive Inspection Techniques**

From June 19–23, 2017, Dr. Budhoo attended a five-day course on "Non-Destructive Inspection Techniques" at Abaris Training facility in Reno, Nevada. This course introduces techniques for identifying and quantifying defects in new or damaged composite panels using the latest equipment, methods, and techniques. The course was very "hands-on" in nature, and quite busy.

The most commonly used Non-Destructive Inspection (NDI) techniques were discussed and practiced in the class. These techniques include Visual Inspection, Tap Testing (both manual and instrumented tap testing), Resonance Bond Testing, Acoustic Emission Testing, Radiographic testing, and Ultrasonic Inspection. Through hands-on practice, Dr. Budhoo gained experience in selecting the methods of inspection which work best on different types of structures (composite and metallic) and on defects.

The knowledge gained from this training will be very helpful in the development of the certificate in composite material course at Vaughn College as well as the manufacturing concentration of the Mechanical Engineering Technology program. These two courses provide students with hands-on experience as well as prepare them for a career in the manufacturing industry. These courses will be offered as two separate classes in the manufacturing concentration of the certificate program.



94

**Vaughn College Professor Participates in Summer Research Program**

Dr. Shouling He, an associate professor in the Department of Engineering and Technology at Vaughn College has been accepted by the NSF sponsored summer research program held at Texas A&M University (TAMU), one of the largest universities in the United States with a board range of research projects funded by NASA, NIH (National Institute of Health), NSF and ONR (Office of Navy Research), etc. The program aims to provide college professors and high school teachers an opportunity to gain research experiences in the areas of Mechatronics, Robotics and Industrial Automation. In addition to conducting research projects with TAMU, professors from different fields such as computer science and engineering, electrical and mechanical engineering and technology, attend a weekly academic seminar. The professors with Ph.D. degrees from Stanford University, UC Berkeley and other universities, present frontier research and developments in the areas of Mechatronics and in Robotics and Industrial Automation. Mobile robot and machine vision is discussed, as well as current developments in bio-robotics and other subjects. The participants are expected to bring their research work into their classrooms and to develop a lesson module to improve education in Robotics and Industrial Automation.

**Adhesive Bonding of Metals and Composites training course at Abaris Training facility Reno, Nevada**

From July 17-21, 2017, Dr. Budhoo attended a five-day training course at Abaris Training facility in Reno, Nevada. The course contained a balance of theory and practical application, with much of the time spent in the lab constructing and testing various test specimens made from aluminum and composite substrates in order to study the effect of different surface preparations.

A comparison of aluminum surface preparation methods was examined using wedge-crack testing per ASTM D-3762 methods and practices. Aluminum plates were prepared using several industry standard methods, including phosphoric acid anodizing (PAA) and sol-gel treatments, as compared to typical abrasion techniques. The plates are bonded with structural film adhesives, cured, and then cut into wedge test specimens. Specimens were also made to evaluate bond line thickness control, utilizing media such as micro beads and knit or scrim carriers with both liquid and paste adhesives. Co-cured composite and secondary bonded aluminum sandwich panel structures were fabricated and tested using a special flatwise-cleavage test. This test revealed the effects at the skin-to-core interface on both foam and Nomex honeycomb core materials.

The knowledge gained from this training will be very helpful in developing an adhesive bonding course at Vaughn College where students will benefit from hands-on experience.



96

**Two of Vaughn's engineering students won 2017 ASHRAE Scholarship Award**

The ASHRAE scholarship is an annual award given by the American Society of Heating, Refrigerating & Air Conditioning Engineers, Long Island Chapter, Region 001. The chapter awards (1) $1000 and (2) $500 scholarships annually to students who are both well-rounded and demonstrate an interest in pursuing an engineering career. Applicants wrote an essay describing their interests, activities, goals and why they deserve the scholarship.

Two students of Vaughn College were recipients of this award, David Adegbesan – first place and Niki Taheri – second place. The award presentation took place at the Westbury Manor in NY, on Tuesday, June 13th at 6 pm. Before the presentation, recipients mingled with each other and with board members of the ASHRAE organization, including representatives from TRANE company.



**Two of Vaughn's Mechatronic Engineering students, David Adegbesan and Niki Taheri, received first and second place 2017 ASHRAE Scholarship awards**

97

**SWE Vaughn Chapter Holds A Workshop at 2017 SWE Annual Conference**
**by Emily German, President of Vaughn's Chapter SWE Club**

The Society of Women Engineers (SWE) 2017 Annual Conference, the world's largest conference and career job fair for women in engineering, was held October 26-28 in Austin, Texas. Vaughn's chapter of the Society of Women Engineers attended and presented at the WE17 Conference. The 11 VCAT-SWE attendees were extremely successful. As a whole, we received 12 interviews with companies such as Northrop Grumman, Lockheed Martin, Daimler Trucks North America, Cummins, Siemens, Medtronic, Nike, and Toyota. Of those 12 interviews, 3 internship offers were made as well as 2 full-time job offers. One of our highlights of the Conference came from Maia Rivers, who received an on the spot, full-time job offer from Oshkosh Corporation.



From left to right, the WE17 attendees are Jessica Jimenez, Grace Davis, Jacqueline Occherio, Emily German, Niki Taheri, Maia Rivers, Sagufta Kapadia, Lovedeep Kaur, and Olivia Hyman

| SWE Conference Attendee with Success | Year | Interviews | Internship Offers | Full-Time Job Offers |
|---|---|---|---|---|
| Niki Taheri | Junior | Toyota | *(Still waiting for response)* | |
| | | Nike | *(Still waiting for response)* | |
| Grace Davis | Junior | Daimler Trucks North America | Daimler Trucks North America | |
| Samantha Maddaloni | Junior | Toyota | *(Still waiting for response)* | |
| | | Siemens | Siemens | |
| | | Medtronic | *(Still waiting for response)* | |
| | | Daimler Trucks North America | Daimler Trucks North America | |
| Jessica Jimenez | Senior | General Dynamics interview - 11/13/17 | | Raytheon *(As a result of internship from last SWE Conference)* |
| | | Cummins | | |
| | | Lockheed Martin | | |
| | | Lockheed Martin 2nd interview - 11/10/17 | | |
| Lovedeep Kaur | Senior | Northrop Grumman | | Northrop Grumman |
| | | | | John Deere *(As a result of internship from last SWE Conference)* |
| Maia Rivers | Senior | | | Oshkosh Corporation |
| Emily German | Senior | | | Daimler Trucks North America *(As a result of internship from last SWE Conference)* |

Due to last year's conference success with internships, this year, Lovedeep Kaur has a full-time offer from John Deere, Jessica Jimenez has a full-time offer from Raytheon, and Emily German has received and accepted a full-time job offer from Daimler Trucks North America. Our previous President, Dimitri Papazoglou, is now an Electrical Engineering PHD student at the University of Dayton. He would not have found his current program and university without his attendance at the WE16 Conference, as well.

**Vaughn's Chapter SWE Members: From left to right, the WE17 attendees are Christina DeLuca, Emily German, Niki Taheri, Grace Davis, and Samantha Maddaloni**

During the conference, two of our VCAT-SWE members also hosted a workshop titled "Do's and Don'ts of STEM Outreach." The room filled up with those interested in STEM outreach; newcomers and veterans of the topic came to the presentation. The presentation focused on what to do and what not to do in your STEM outreach workshop or course. Featured topics related to picking your students, keeping control of your class, employing hands-on activities and handling students who are familiar with your topic. The presentation also used videos of SWE members acting out skits to showcase ideas.
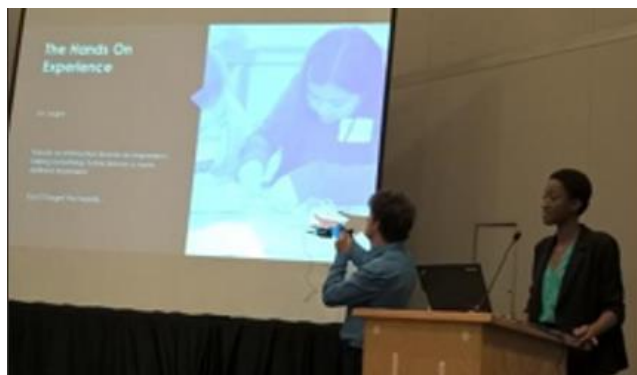


Dimitri Papazoglou and Olivia Hyman presenting the "Do's and Don'ts of STEM Outreach" at the WE17 Annual Conference

As we anxiously wait for responses from our other interviews, we would like to thank the President of Vaughn College, Sharon Devivo, the chair of the Department of Engineering and Technology, Dr. Hossein Rahemi, the Assistant Vice President of Development and Alumni Affairs, Michael Brady, the Executive Director of Career Services, Philip Meade, the Associate Director of Career Services, Jessica Caron, the Internship Coordinator of Career Services, Sean Manning, the Interim Vice President of Student Affairs, Kathy Deaner, and VACT-SWE's adviser, Dr. Shouling He for their consistent support for SWE Vaughn College activities. Concurrently, as the President of the Society of Women Engineers, Vaughn Chapter, I would like the thank Niki Taheri, Sagufta Kapadia, Grace Davis, Christina DeLuca, Maia Rivers, Olivia Hyman, Lovedeep Kaur, Samantha Maddaloni, Jacqueline Oricchio, Jessica Jimenez, and Dimitri Papazoglou for their hard work in preparing for the conference. We would not have been as successful as we were without everyone's efforts.

**2017 VEX U Robotics World Championship Competition "Starstruck Game"**
**Vaughn Robotics Team finishes 3rd in 2017 VEX U Robotics World Champion**

Every year, VEX Robotics challenges the problem-solving skills of science, technology, engineering and math (STEM) scholars. Competition participants used robotics platforms and engineering processes to solve this year's challenge entitled 'Starstruck Game." For this purpose, Vaughn's team designed, built, and programmed a robot to compete in matches consisting of a forty-five second autonomous period followed by one minute and fifteen seconds of driver-controlled manipulation. The team constructed their robot to attain the following objectives:

1. One robot that can be separated to two robots; perform fast, and score consistently through both autonomous driver-controlled modes.
2. A robot that has the best defensive and offensive performance
3. A robot with control algorithms for the best autonomous performance
4. A structurally reliable robot in compliance with the limitations and constraints of the challenge.

Both robots are connected together through a wiring mechanism, and during the competition they can be separated into two robots to perform better than the opposing alliance through the capability to score stars and cubes into one of the two zones, as well as perform a hang. At the beginning of the match, the robot starts off smaller than the 24"x24"x24" cube size limit, but once the match starts, the robot splits into two robots and expands outside of the 24"x24"x24" size limitation to any size specs it requires.
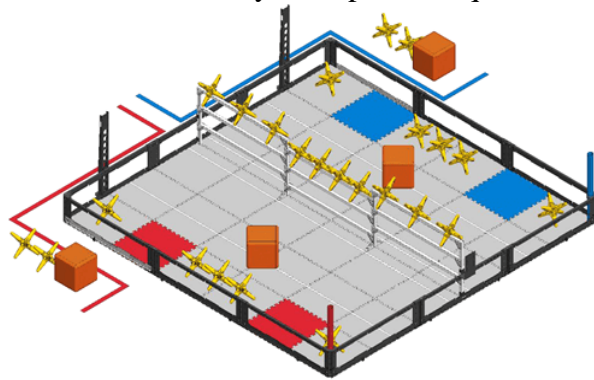


From April 19-22, sixty-two national and international universities and colleges were invited to the 2017 VEX U World Championship in Louisville, Kentucky Freedom Expo Center. Invitation to the VEX U Robotics World championship was only granted to a team that is a tournament champion or an "Excellence" award recipient of a regional competition, and Vaughn's Robotics team were tournament champ of the College of Southern Maryland (CSM) regional Qualifier, recipient of the "Excellence" award of the Vaughn College Regional Robotics Competition, as well as tournament champion of the Mexican VEX U Reeduca International robotics competition.

This intense three-day competition was challenging, and our team was continually modifying their robots and autonomous programming to be competitive with other top teams in this tournament. During Thursday and Friday, Vaughn's team won all its eight qualifying matches. and ranked 1st in the "Innovate" division

100

During Saturday matches, due to a wiring issue with one of the robots, VCAT lost one of its qualifying matches. With nine wins, Vaughn's team ranked 3$^{rd}$ in the "Innovate" division of the world championship, and automatically qualified for the Saturday afternoon playoff round. In the quarter-final, the top eight teams competed, and Vaughn's team defeated a team from China thus advancing to the semifinal playoff round against AURA (a team from University of Auckland, New Zealand). In an intense semifinal game of tournament matches (best of two out of three) AURA won the first match, VCAT won the 2$^{nd}$ match, and during the third match AURA defeated the VCAT team and advanced to the world tournament championship against IFR and ultimately winning the 2017 World tournament championship.
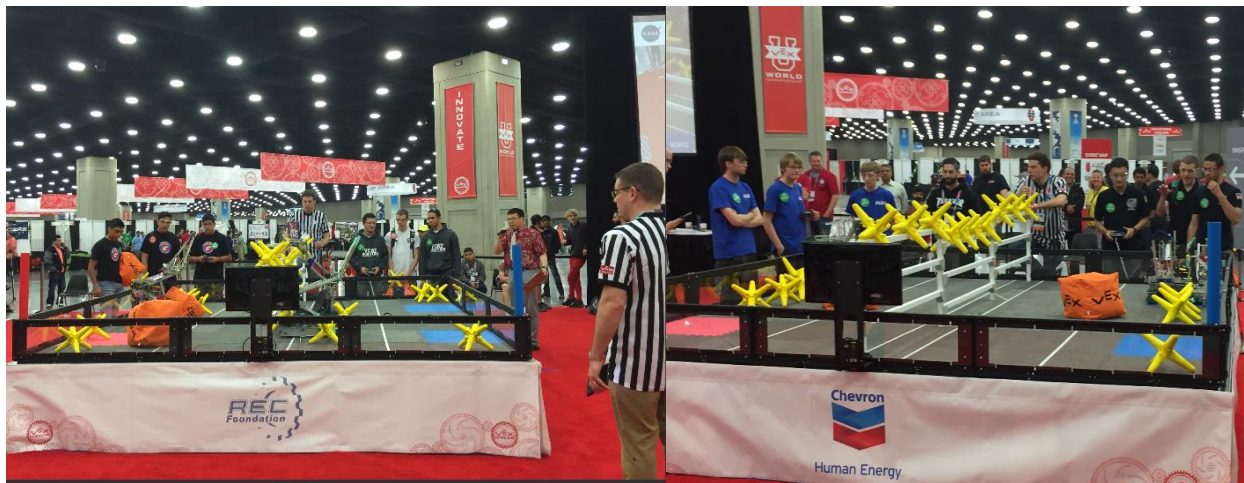




The world championship is a tough competition in which only the top US regional and world champions qualify to participate. VCAT has the third top team in the world in this challenging competition, and they retained their standing as one of the 2017 top ranked competitors in the world championship by advancing to the playoff round of this intense competition for four years in a row.

101

**2017 VEX U Robotics World Championship Competition**

**Mexico's VEX U Reeduca Robotics Competition, November 11, 2017**

The Vaughn College Robotics team, one of the top three competitors in 2017 VEX U Robotics world championship, was invited to participate in Mexico's VEX U Reeduca Robotics competition as part of the Torneo VEX-Reeduca de la Zona Noreste 2017-2018**.** On November 11, 15 teams, including Vaughn College Robotics, participated in Mexico's VEX in the Zone Challenge competition in the American School of Tampico, Tamaulipas, Mexico.   Seven members of Vaughn College robotic club (Norrin Abreu, Niki Taheri, Jason Becker, Juan Rodriguez, Atif Saeed, John Hernandez, and Nizamadeen Khedaru) and two advisors, Dr. Hossein Rahemi and Prof. Khalid Mouaouya, represented Vaughn College at this competition.

The competition was challenging; during Saturday November 11 qualifying competition, our team competed against 8 Mexican teams and Vaughn won 6 out of its eight matches. With 6 wins Vaughn's team received automatic qualification for the playoff round. During playoff round, Vaughn's team remained undefeated through the quarterfinals, semifinals, and final finished first by winning the tournament championship of this international competition. Vaughn robotics team members consistently demonstrated persistence and drive in order to attain their title as champions of Mexico's VEX U Robotics competitions for three years in a row.

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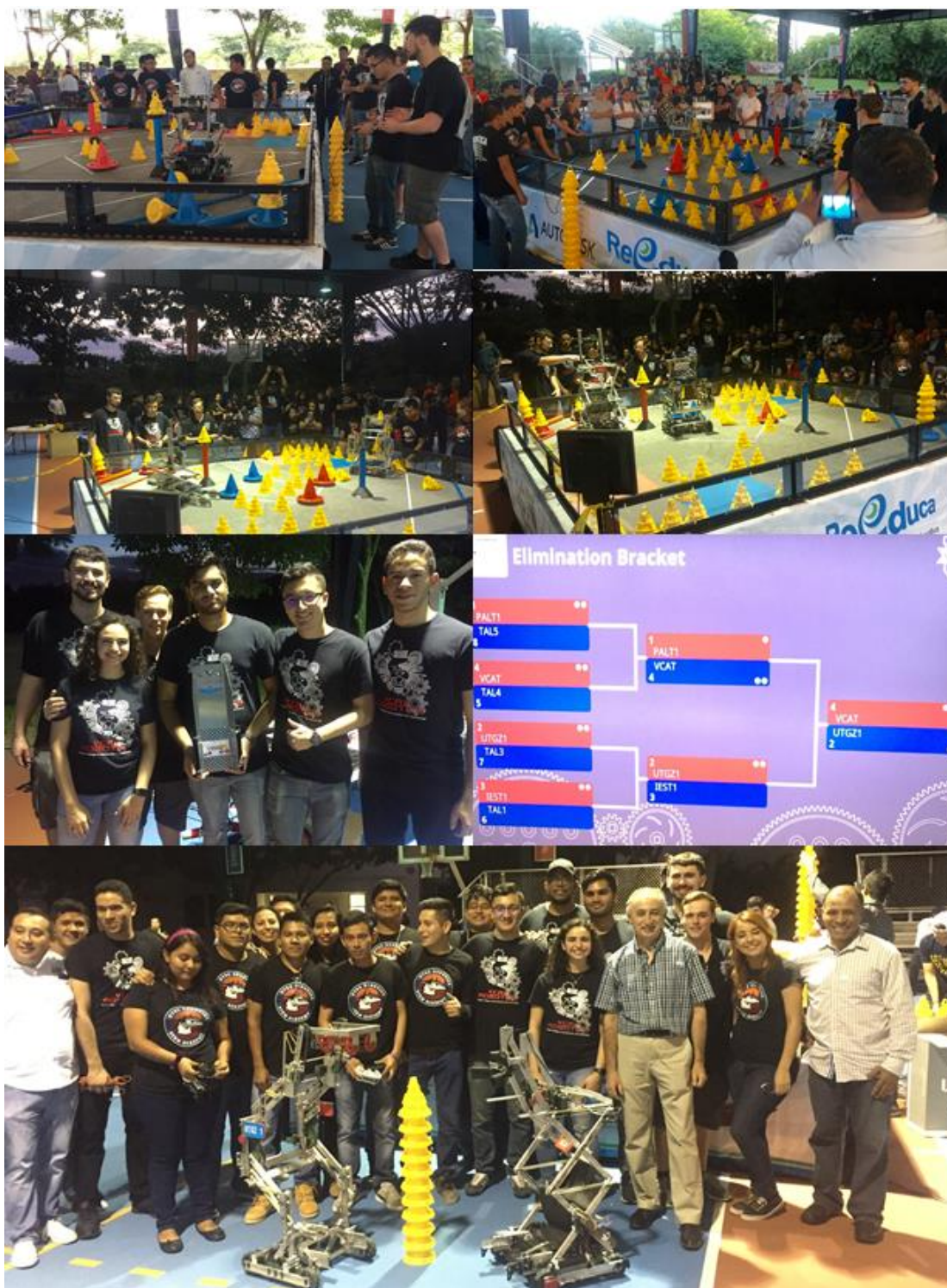
**Mexico's VEX U Reeduca Robotics competition, November 11, 2017**
Vaughn's Robotics Team wins Tournament Champion

**VEX Robotics Fall Scrimmage, Vaughn College, December 9, 2017**

Vaughn College hosted a fall practice scrimmage on Saturday December 9, 2017 where teams from four northeast colleges came to Vaughn to hone their skills and strategy before participation in spring regional qualifying matches.

A total of eight teams, including New York Institute of Technology, New Jersey Institute of Technology, IFT Robotics, Rochester Institute of Technology, Bergen Community College, and Vaughn College, participated in fall scrimmage matches. The event began at 9 am with check-in and robot inspection followed by skill challenges and qualification rounds. During playoff round, Vaughn's team advanced to the finals where they faced IFT, a finalist of the 2017 world championship. In an intense final game of scrimmage matches (best two out of three), VCAT team with two wins finished first, and IFT finished second.
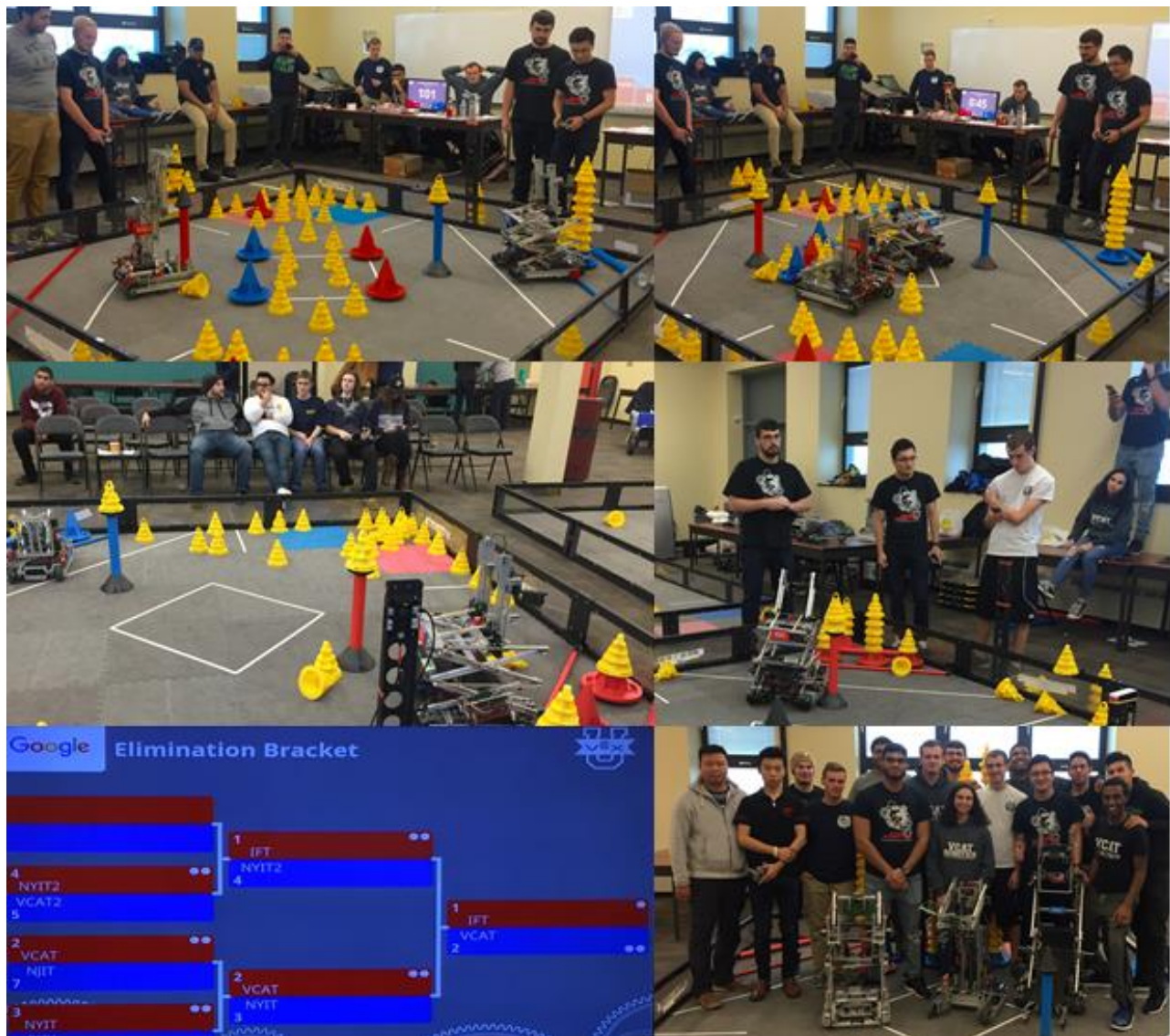


**VEX U Robotics Fall Scrimmage, December 9, 2017**

**Vaughn College Hosted VEX High School Robotics Qualifier Competition on Saturday, January 13th, 2018**

Vaughn College of Aeronautics and Technology hosted its fourth high school robotics competition on Saturday January 13th, 2018. A total of 37 regional high schools from Queens, Brooklyn, Bronx, Nassau, and Suffolk counties attended the January VEX state qualifier at Vaughn College. The list of high school participants is as follows:

## Team List                                                                 ( 37 Teams )

| Team | Team Name | Organization | Location |
|------|-----------|--------------|----------|
| 199A | Wisdom Warrior | Wisdom Lane MS | Levittown, New York, United States |
| 699E | Eve-09 | Thomas A. Edison CTE High School | Jamaica, New York, United States |
| 699T | RoboTex | Thomas A. Edison CTE High School | Jamaica, New York, United States |
| 699Z | Andromeda | Thomas A. Edison CTE High School | Jamaica, New York, United States |
| 1058A | Elwood | Elwood HS | Elwood, New York, United States |
| 1353A | Robodalers | Farmingdale High School | Farmingdale, New York, United States |
| 1353C | VEXcalibur | Farmingdale High School | Farmingdale, New York, United States |
| 5059B | FA Robo-Quaker | Friends Academy | Locust Valley, New York, United States |
| 6277A | RoboCavs | The Harvey School | Katonah, New York, United States |
| 6277B | RoboCavs | The Harvey School | Katonah, New York, United States |
| 6277C | RoboCavs | The Harvey School | Katonah, New York, United States |
| 6277D | RoboCavs | The Harvey School | Katonah, New York, United States |
| 9717A | St. Catharine Comets | St. Catharine Academy | Bronx, New York, United States |
| 9717B | St. Catharine Comets | St. Catharine Academy | Bronx, New York, United States |
| 9932A | Hawks | Jericho High School | Jericho, New York, United States |
| 9932B | Hawks | Jericho High School | Jericho, New York, United States |
| 9932C | Hawks | Jericho High School | Jericho, New York, United States |
| 9932D | Hawks | Jericho High School | Jericho, New York, United States |
| 9932E | Hawks | Jericho High School | Jericho, New York, United States |

| 9932F | Hawks | Jericho High School | Jericho, New York, United States |
|---|---|---|---|
| 9932G | Hawks | Jericho High School | Jericho, New York, United States |
| 9932H | Hawks | Jericho High School | Jericho, New York, United States |
| 9932J | Hawks | Jericho High School | Jericho, New York, United States |
| 11570A | Cyclones Robotics | South Side High School | New York, New York, United States |
| 11570B | Cyclones Robotics | South Side High School | New York, New York, United States |
| 11570C | Cyclones Robotics | South Side High School | New York, New York, United States |
| 11570D | Cyclones Robotics | South Side High School | New York, New York, United States |
| 16099A | Overclock | KG Computech | Flushing, New York, United States |
| 16099B | Overclock | KG Computech | Flushing, New York, United States |
| 68602A | GC Robots | Garden City High School | Garden City, New York, United States |
| 68602B | GC Robots | Garden City High School | Garden City, New York, United States |
| 76194A | Dragons | Division Avenue High School | Levittown , New York, United States |
| 97140A | Kennedy Gaels | Kennedy Catholic High School | Somers, New York, United States |
| 98456A | Robo Frog | St. Mary's Episcopal Church | Carle Place, New York, United States |
| 98456B | Men in Black | St. Mary's Episcopal Church | Carle Place, New York, United States |
| 98570A | Babylon Panthers | Babylon UFSD | Babylon, New York, United States |
| 98570B | Babylon Panthers | Babylon UFSD | Babylon, New York, United States |

The members of the VCAT robotics team organized and acted as referees for the event. Bilal Rashid and Jason Becker served as manager and event planner; Atif Saeed served as the announcer. Vaughn faculty members Prof. Jesus Manuel, Dr. Benalla Mohammed, Prof. Johnathan Sypeck, Prof. Bobby Tang, and Frank Wang served as the judges for this competition.

**High School VEX Robotics State Qualifier Competition, Saturday, January 13<sup>th,</sup> 2018**

The table below provides the list of award recipients for the 2018 regional High School VEX Robotics State Qualifier Competition. An alliance of KG Computech and The Harvey School won the tournament championship, while a team from Jericho High School won the "Excellence" Award, and KG Computech won "Robot Skills." Tournament champions, "Excellence" Award, and "Robot Skills" Winner qualified to participate in the New York State VEX Championship.

| Award | Team # | Team Name | Affiliation | Location |
|---|---|---|---|---|
| Excellence Award (VRC/VEXU) | 9932A | Hawks | Jericho High School | Jericho, New York, United States |
| Tournament Champions (VRC/VEXU) | 16099B | Overclock | KG Computech | Flushing, New York, United States |
| Tournament Champions (VRC/VEXU) | 16099A | Overclock | KG Computech | Flushing, New York, United States |
| Tournament Champions (VRC/VEXU) | 6277C | RoboCavs | The Harvey School | Katonah, New York, United States |
| Innovate Award (VRC/VEXU) | 9717B | St. Catharine Comets | St. Catharine Academy | Bronx, New York, United States |
| Create Award (VRC/VEXU) | 6277A | RoboCavs | The Harvey School | Katonah, New York, United States |
| Build Award (VRC/VEXU) | 1353A | Robodalers | Farmingdale High School | Farmingdale, New York, United States |
| Design Award (VRC/VEXU) | 9932E | Hawks | Jericho High School | Jericho, New York, United States |
| Judges Award (VRC/VEXU) | 199A | Wisdom Warrior | Wisdom Lane MS | Levittown, New York, United States |
| Tournament Finalists (VRC/VEXU) | 5059B | FA Robo-Quaker | Friends Academy | Locust Valley, New York, United States |
| Tournament Finalists (VRC/VEXU) | 97140A | Kennedy Gaels | Kennedy Catholic High School | Somers, New York, United States |
| Tournament Finalists (VRC/VEXU) | 6277A | RoboCavs | The Harvey School | Katonah, New York, United States |
| Robot Skills Winner (VRC/VEXU) | 16099A | Overclock | KG Computech | Flushing, New York, United States |
| Energy Award (VRC/VEXU) | 699E | Eve-09 | Thomas A. Edison CTE High School | Jamaica, New York, United States |
| Sportsmanship (VRC/VEXU) | 199A | Wisdom Warrior | Wisdom Lane MS | Levittown, New York, United States |

**Vaughn College hosted VEX U Robotics Regional Qualifier on Saturday January 27, 2018; Vaughn's Robotics Team wins 2018 VEX U Skill Challenge and Tournament Champion Awards**

Vaughn College of Aeronautics and Technology hosted its fifth VEX U College Regional Robotics competition on Saturday January 27, 2018. A total of thirteen college teams participated at this event. The participant teams included Worcester Polytechnic Institute (two teams, WPI0 & WPI1), Kennesaw State University (two teams, OWL1 and OWL2), Rutgers University (RUSK), New York Institute of Technology (three teams, NYIT, NYIT2 and NYIT3), University at Buffalo (UBR), Johnson & Wales University (JWU), Aquidneck Island Robotics, and Vaughn College of Aeronautics and Technology (VCAT).

Four members of Vaughn College robotic club (Norris Abreu, Jason Becker, Juan Aguirre, John Hernandez, Thomas Wolday) represented Vaughn team (VCAT) at this competition. Also, Eric Grieco, Nizamadeen Khedaru, and Thomas Wolday served as referees, and Bilal Rashid served as the event manager. Atif Saeed served as announcer, while Niki Taheri, Andryi Belz, and other Vaughn's robotics team members were involved with Robots inspection, setting up the fields and facilitating the implementation process for this event. Also, Emily German (president of SWE Club), Utsav Shah (President of UAV club), Bobby Tang (adjunct faculty) served as judges for this competition.

During the skills challenge matches, Vaughn's team finished first in "Robot Skills" (125 points). Each participating team had a total of six matches. With six wins Vaughn's team received first ranking in qualification matches and advanced to the playoff elimination round. During the playoff rounds VCAT defeated all of their opponents (WPI1, NYIT2, and WPI0) and won tournament champion of this regional competition. The results of the eliminations rounds (best of two out of three) are as follows:

| Quarterfinals | | | Semifinals | | | Finals | | |
|---|---|---|---|---|---|---|---|---|
| Match 1 | Match 2 | Match 3 | Match 1 | Match 2 | Match 3 | Match 1 | Match 2 | Match 3 |
| VCAT 87 | VCAT 74 | | VCAT 109 | VCAT 93 | | VCAT 95 | VCAT 78 | VCAT 84 |
| WPI1 0 | WPI1 42 | | NYIT2 36 | NYIT2 44 | | WPI0 59 | WPI0 82 | WPI0 78 |

In this regional completion, Vaughn's robotics team won first place skills' award, tournament champion award, and a qualification to participate in the 2018 VEX U World Robotics Championship.
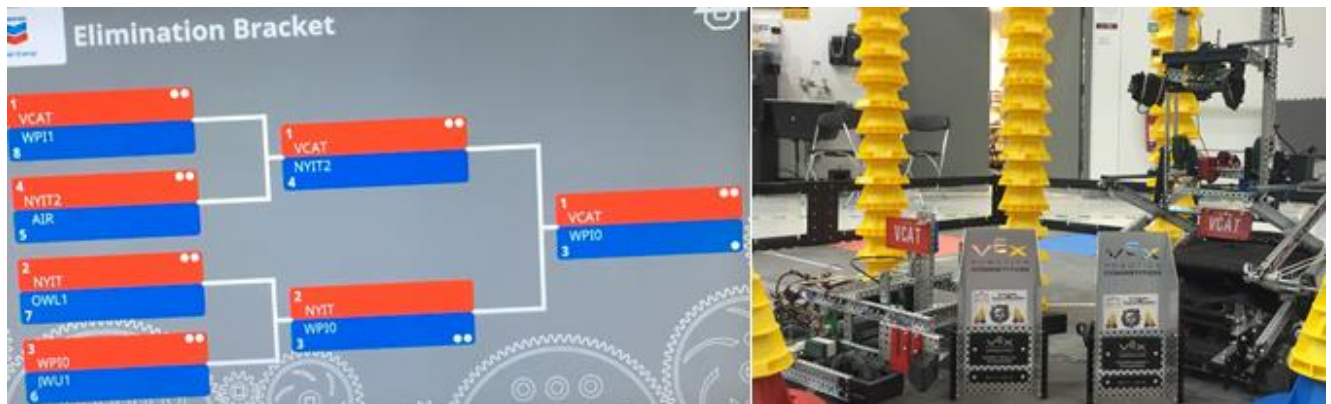
**Teams fixing their robots and getting ready for competition**

**Vaughn's Robotics team finished first in skill challenge competitions and received first place award from Mr. Ken Stauffer, a member of Vaughn's Board of Trustees**

**Vaughn's Robotics team wins all its qualification matches and with total score of 212, received first place ranking in playoff elimination round**

**Vaughn's Robotics team wins tournament champion award and WPI team wins "Finalist" award at Vaughn's 2018 VEX U Robotics Regional Qualifier**

**2018 West Virginia VEX U Robotics Regional Qualifier Competition, March 2, 2018**

On Friday March 2, 2018, Vaughn College's Robotics team participated at the Fairmount State University VEX U Robotics Regional Tournament. The team was composed of ten members (Norris Abreu, Juan Aguirre, Jason Becker, Niki Taheri, John Hernandez, Atif Saeed, Andryi Belz, Manny Duenas, Timothy Tullio, and Nicholas Harrington) along with department chair, Dr. Hossein Rahemi.

A total of nineteen colleges and universities participated in the event. The participant teams included two teams from Virginia Tech (TEKVT, VTTEK), three teams from Rutgers (RUSK, RUSK1 and RUSK2), University of Maryland Baltimore (UMBC), Rochester Institute Of Technology (RIT1), NJIT, West Virginia University Institute of Technology, Liberty University, Johnson & Wales University (JWU), Old Demonian University (ODU11), two teams from Northern Virginia Community College (NOVA2 and NOVA3), Bridge Valley Community and Technical College (BV1), two teams from College of Southern Maryland (CSM &CSM2), Aquidneck Island Robotics (AIR), and Vaughn College of Aeronautics and Technology (VCAT2).

Each participating team had a total of six matches. Vaughn's team won all of its six qualifying matches and advanced to the 1$^{st}$ place seating of the playoff round. During the elimination of playoff rounds, VCAT defeated all of their opponents thus advancing to the finals where they faced CSM. In an intense final game of tournament matches (2 best out of three); CSM won the first match, VCAT won the 2nd match, and in a very close match, CSM won the third match (CSM 77, VCAT 74) and the tournament championship. VCAT2 won both "Finalist" and "Robot Skills" championship awards which qualifies the VCAT2 team to participate in the 2018 VEX U world championship.
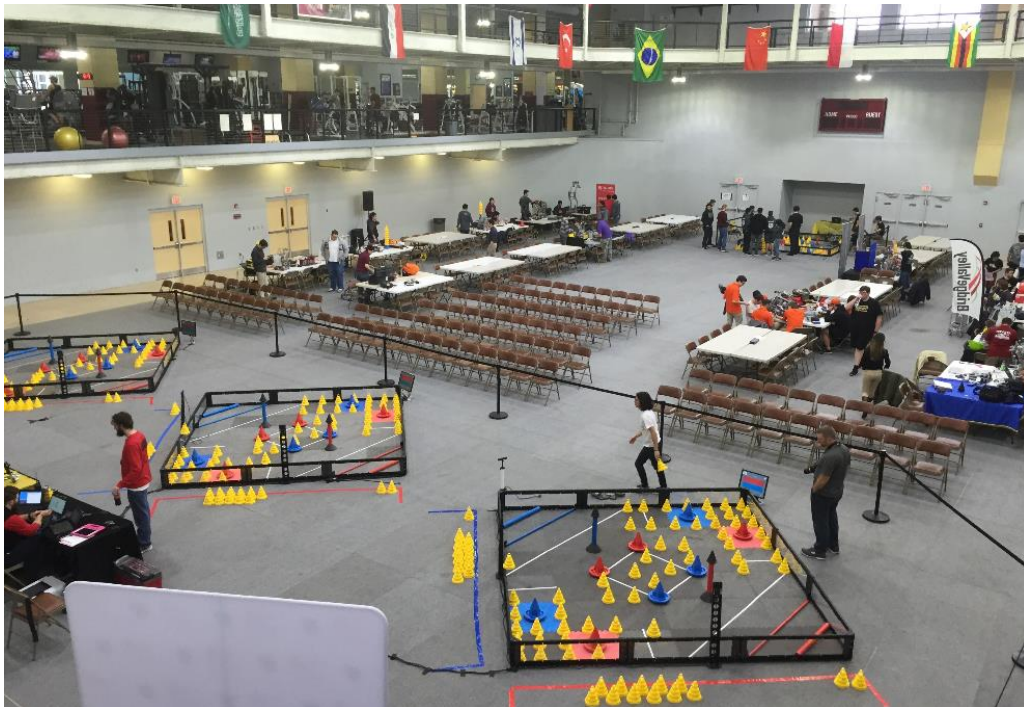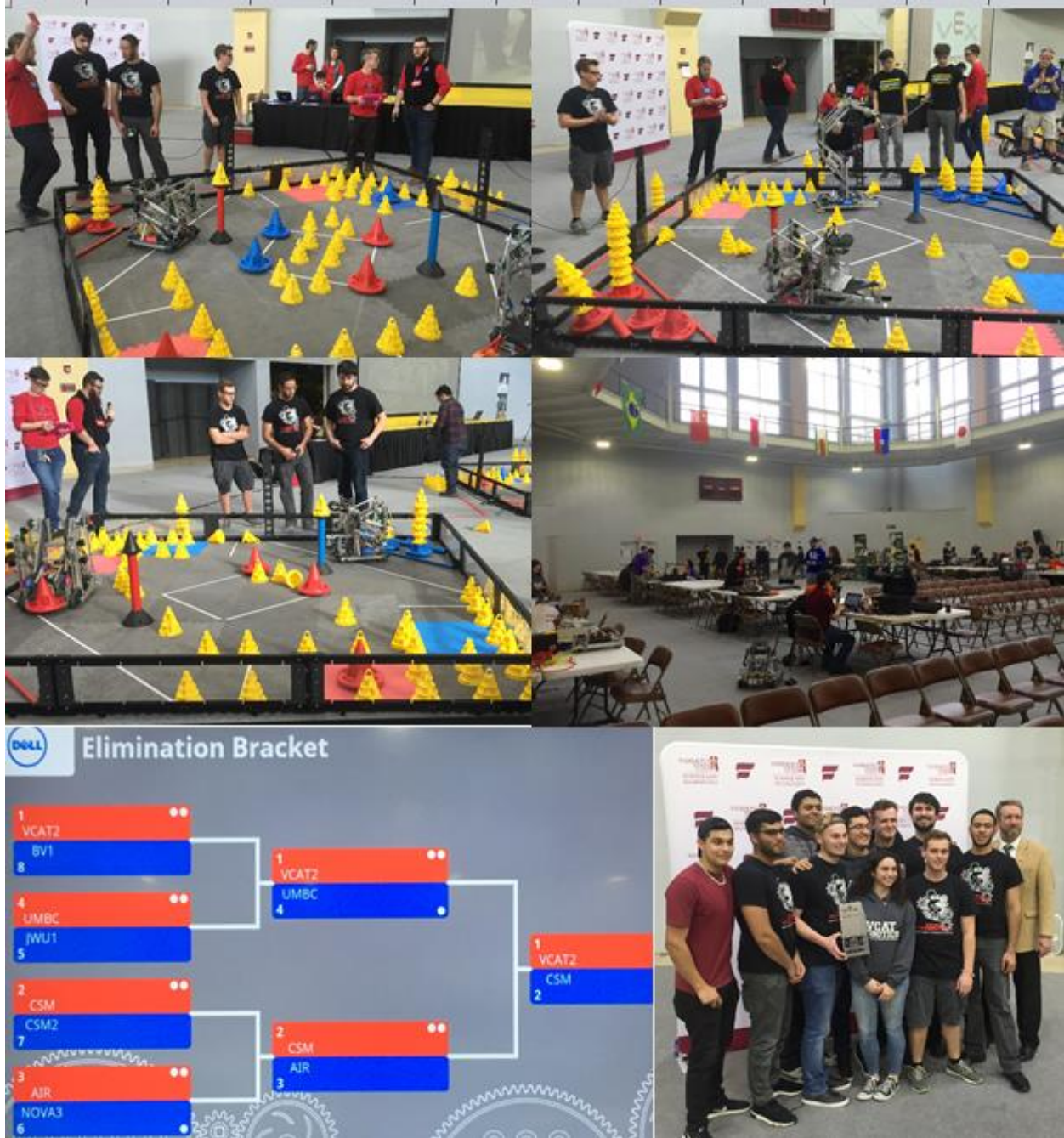
**VCAT2 wins both "Finalist "and "Robot Skills" championship awards at Fairmount State University Regional 2018 VEX U competitions**

**2017-2018 Vaughn College of Aeronautics and Technology UAV Club Activities**

The UAV Club was established three years ago by undergraduate students desirous of more than the theoretical knowledge provided by their classes and who wish to participate in innovative developments in technology. In the past 3 years, the club has grown exponentially in its member size (600%), and it has gained a reputation not only in Vaughn College of Aeronautics and Technology but also in the American Helicopter Society where the UAV Club team won second place in the USA 2017 Micro Aerial Vehicle competition. Members in the club work on drones made for a variety of uses such as racing or photography and they use a gimbal for stabilization to autonomous vehicles. The Club members use a single board computer like NVIDIA TK1 and Raspberry Pi for image recognition applications. They also use Robot Operating Software (ROS) to program autonomous drones. Some of the club members are becoming experienced in machine learning which they are planning to implement upon drones. Using single board computers like NVIDIA TK1 helps club members create deep neural networks, and GPU enables them to compute tasks much faster than with a traditional CPU.

The UAV club is constantly growing and developing as the members continue to advance their knowledge on various drone-related topics including autonomous systems (single board computer, sensor, flight controller, image processing, etc.), frame structure, motors, and ESCs. The club members visited the Maker Faire on September 23rd, 2017 as a gateway to knowledge about the work other drone enthusiasts and companies are currently researching, have already developed or are planning to conduct in the future. Some of the booths members visited included - Aerial Sports League (ASL), BeagleBoard, University of Penn State and a few others. This was a great experience for the club members because they had the opportunity to speak with professionals and graduate students in the field.
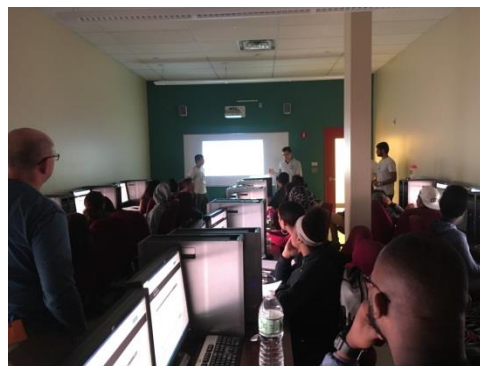
**STEM Outreach and Workshops:** The UAV club is involved in more than just research and drone design. It is also extensively involved in community outreach, holding workshops and presentations for middle school and high school students. In our rapidly developing world, the exposure of the younger generation to drones, through these workshops, promotes an awareness they can build on, in the future. During the fall semester, the UAV club held multiple workshops including the Bi-Directional motor control workshop on Manufacturing Day and the Digi Drones workshop for Nassau Community College's GEAR UP Next GEN STEM Day. These workshops enabled the youth to gain basic programming skills as well as understand how a circuit is put together. These workshops also enable them in the use of Arduino Nano, which provides a basic understanding

of how a microcontroller works. By exposing youth to these concepts at an early age, the UAV club believes these students will grasp difficult concepts of engineering and drones in the future.
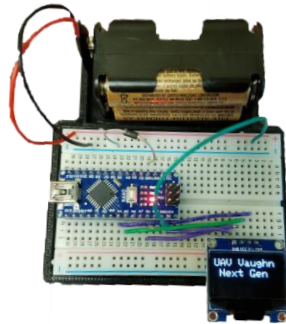


To raise money for the required equipment and parts, the UAV club raffled off one of the DJI's most popular drones, Spark. The Spark is valued at $500 and has some of the most advanced features on the market. These features include hand gesture control, a camera with a 1/2.3" sensor (12MP and 1080p 30fps), 2 axis gimbal, and 16 min flight time. The raffle allowed the club to make enough money to buy some parts; however, the money raised was not enough to purchase all equipment. The club thus continues to fundraise in other ways and to apply for grants in order to fulfill its financial needs.

The UAV club also hosts various events during the spring 2018 semester. The first event, Zero Gravity FPV Racing, takes place on February 2nd 2018, in the hanger. In this event, a group of Drone enthusiasts, namely Zero Gravity, along with the UAV club members, fly their drones in the Vaughn College hanger with First Person View (FPV) goggles. This event is free for all Vaughn College students interested in attending. Additionally, as the UAV club continues to do community outreach by assisting Cradle of Aviation, for the second year in a row, as drone consultants by setting up and judging a LEGO drone competition for middle school students. The UAV club also hosts workshops for high school and middle school students on Technology Day. This club also hosts one of its biggest events, International Drone Day (IDD), an open and free event for everyone to attend. Various drone enthusiasts such as Zero Gravity and leading Drone companies like DJI are invited to the event, and there is a speaker panel during which the attendees have the opportunity to speak with professionals from the drone law industry. The UAV club holds multiple workshops at this event, including a workshop for programming and building a drone. However, the most fun part of the event is in the hanger where an obstacle course is set up inside the netted area for everyone who is interested in flying one of UAV Club's drones.

The UAV Club plans to participate in the American Helicopter Society's (AHS) 6th Annual Micro Aerial Vehicle Student Challenge. This year's competition features a package delivery mission which includes avoiding obstacles and finding targets. The real challenge of the competition is that the drone should use data only from its onboard sensors. The drone is expected to do the following tasks - pick up the package from the home base, go to the delivery area and find the delivery target location. Once the delivery target is located, the drone should drop off the package and start the search for the pickup target location. When found, the drone is supposed to pick up the package and return to the home base while avoiding a wall which functions as an obstacle. This task can be accomplished either by a remotely operated or by a fully autonomous drone. The UAV Club plans to take part in both the manual and the autonomous category. For the autonomous category, the team is led by the President of the club, Utsav Shah, and for the manual category, the team is led by Chamathke Perera, a skilled member of the UAV Club.
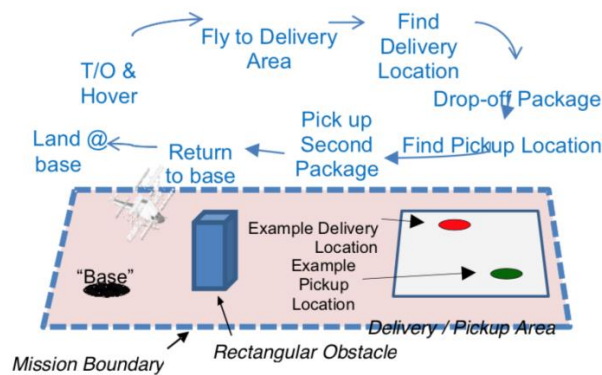


| Task B, Mission Phase | Qualitative Criteria | Rating ID (0-5) |
|---|---|---|
| Take off & Hover | 2 m (6 ft.) hover height above base. Metrics: Time to stable hover & Hover stability. | Q1 |
| En Route to Delivery/Pickup Area | Transition to this phase with clearly-announced user signal. Metrics: Qualitative smoothness of transitions and Time to reach delivery area. | Q2 |
| Obstacle Avoidance | Avoid obstacles between the home base and the target search area. Metrics: Successful avoidance, Smoothness of flight around obstacles. | Q3 |
| Target Search | Remote operator or Autonomous system will use only onboard camera(s) to find each target. Metrics: Time to find target, Operator involvement | Q4 |
| Target Acquisition | Establish a stable hover for at least 5 seconds over each delivery/pickup location target. Smoothly transition between searching, hover, and drop-off/pickup. Metrics: Lateral target tracking error, Stable roll/pitch performance | Q5 |
| En Route Return to Base | Transition to this phase with user signal. Remote operator can use LOS. "Base" can use homing beacons for autonomous RTB. Metrics: Qualitative smoothness of transitions, Time to acquire stable hover over base | Q6 |
| Hover and Landing | Acquire stable hover 2 m (6 ft.) above base before landing. Metrics: Hover and landing performance, distance from center. | Q7 |

To participate in the competition, once they submit their Gate 1 and Gate 2 papers, the teams must receive an email notification of their participation in the finals. The Gate 1 paper (due January 31$^{st}$) is a 5-page abstract identifying the key student and faculty member involved, vehicle specifications and capabilities, the onboard system and remote operation development proposal, and the preliminary plan. The Gate 2 paper (due March 16$^{th}$) includes a progress report of the final vehicle, system configuration, and a video proof of the vehicle capabilities. The video must clearly demonstrate the final vehicle dimensions, weight, and competition readiness. Teams should include image processing results, autonomous maneuvering, live data feed to the ground control station and a kill switch.

**National Society of Black Engineers (NSBE) Club Activities**

The National Society of Black Engineers is a worldwide organization focused upon member success both in and out of school. There are a number of programs and events throughout the year that provide our membership and the student body with internship and networking opportunities. Multiple events, such as host study groups and fun outings, are held within this organization. Our national club goal, stated within the NSBE mission statement is "To increase the number of culturally responsible black engineers who excel academically, succeed professionally, and positively impact the community."

The Vaughn College Chapter of The National Society of Black Engineers was officially established in February 2018. This chapter is paving the way for engineers as well as changing the world. Even though it's a new chapter, there have been a growing number of active members and events that uphold the mission of the organization.

## Engineering Your Future

On October 2018, the VCAT Society of Hispanic Professional Engineers created a professional development workshop called "Engineering Your Future". The various engineering companies involved were Cyient, Con Edison, Duro USA, AAR, and Pratt & Whitney. The purpose of this event is to prepare engineering students for their professional career fields. Students receive professional advice, mock interviews, resume revision, and even personal LinkedIn assessment. Events such as this one will be executed annually to ensure that students are prepared for their careers post-graduation.

## NSBE National Convention 43

The National Convention for NSBE was held in Kansas City, Missouri from March 29th to April 2nd, 2017. A few of our members represented our chapter at the convention. This event exposed our members to workshops which prepare them to excel academically, succeed professionally,

and have a positive impact on their local communities. In addition, a career fair is held for two days which allows members to receive an internship or full time position from among over 300 companies. Opportunities are also available at the convention for members to participate in various competitions and attend workshops. The career fair also provides members with the opportunity to pursue success both pre and post- graduation.

## Hidden Figures Watch Party

In November 2017, our chapter screened the film *Hidden Figures,* an event that allowed students on campus to engage and interact with each other. This movie has relevance in regards to the need for diversity in STEM fields, since it is about the contribution of women of color, who were employees at NASA, to the "race to Space". The event also involved a discussion on how to successfully plan outreach workshops.

## Regional Leadership Conference

In August 2017, the NSBE held an annual leadership conference for its region. The purpose of this event was to prepare members who hold positions on the executive board to execute their positions properly. Members attended workshops and team building activities with various companies, activities which enabled them to better understand their leadership roles.

## Fall Region 1 Conference

Some of the current members of our chapter were able to attend the Fall Regional Conference (FRC) which involved the collaboration of all the chapters in our region. There were workshops that varied from "How to Fund Your Chapter" to "Be Authentic on Interviews." On the last day of the event, a career fair was held with companies such as General Motors, United Technologies, and Rockwell Automation. At this event, our chapter received the "Rising Chapter" award, recognizing the growth of our relatively new chapter.

**Society of Women Engineers (SWE) Activities**
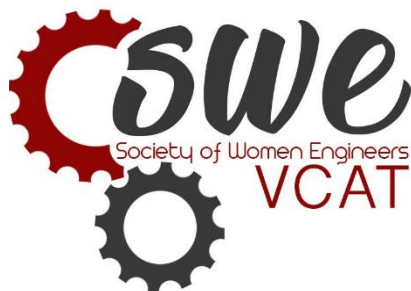


The Vaughn College of Aeronautics and Technology (VCAT) Chapter of the Society of Women Engineers (SWE) is an organization that supports and empowers female students who are specializing in the field of engineering. The Chapter's goal is to highlight the importance of diversity and strengthen its legacy in a very competitive field. Not only does the chapter groom its members to excel as engineers, it also helps them to become well-prepared professionals who will be highly productive in their chosen field of endeavor. The chapter also prides itself on its STEM outreach, in hopes of increasing future female involvement in engineering.

## 2017 ASEE Mid-Atlantic Conference

On October 7th, the President of Vaughn's SWE Chapter, Emily German, and the Vice-President of Vaughn's SWE Chapter, Niki Taheri, with help from the SWE Club Advisor, Dr. Shouling He, wrote and published "Initiating Engineering Learning for Minority Students in Elementary Schools" at the 2017 ASEE Mid-Atlantic Conference. Ms. German and Ms. Taheri also presented the paper at Penn State Berks in Reading, Pennsylvania. The success of the presentation and of the workshop the paper discussed caught the attention of Queens Community College's Physics department, who offered a partnership between VCAT SWE and their department. Thanks to this partnership, SWE will be hosting workshops on particle ray detectors at which they will teach high school students how to read this data.

## WE17 Conference

Between October 26, 2017 and October 28, 2017, Vaughn College's chapter of the Society of Women Engineers attended and presented at the WE17 Conference in Austin, Texas. The 11 VCAT-SWE attendees were very successful at securing offers of employment. As a whole, we received 12 interviews with companies such as Northrup Grumman, Lockheed Martin, Daimler Trucks North America, Cummins, Siemens, Medtronic, Nike, and Toyota. As a result of these interviews, 3 internship offers, and 2 full-time job offers were made. One of the highlights of the conference is that Maia Rivers received an on spot, full-time job offer from Oshkosh Corporation. At the present time, all senior VCAT SWE members have full time job offers or will be furthering their education after their graduation in May of 2018.

During the conference, two of our VCAT-SWE members also hosted the presentation "Do's and Don'ts of STEM Outreach". The room filled up with those interested in STEM outreach, newcomers, and veterans of the topic. The presentation featured topics on picking your students, keeping control of your class, the importance of hands on activities, and tips on how to handle students familiar with your topic. The presentation also used videos of SWE members acting out skits to showcase ideas.

## SWE STEM Outreach

The purpose of the workshops was to introduce students from K to 12th grade to the world of STEM by showcasing fun products to construct using a theoretical background. These activities use basic concepts of Mechanical Engineering, Electrical Engineering, or Computer Science and bring to light fields to women that they otherwise may have not considered. These workshops are presented visually, verbally, and kinesthetically to enhance the overall understanding of the students.
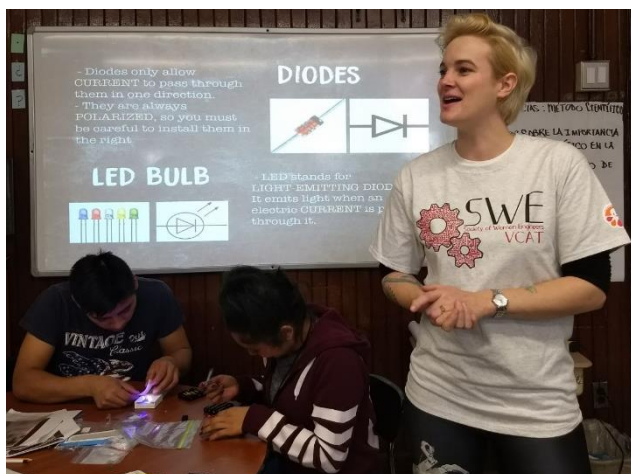


Our first STEM Outreach workshop was held by Samantha Vitez on December 1st. She successfully presented the "Magic 6 Board" to 20 high school ESL Students and explained the electrical engineering concepts needed to understand their project. Students were taught the fundamentals of current and voltage, as well as how to use resistors, capacitors, diodes, LEDs and switches. After learning the basics, the students were given step-by-step instructions on how to build their own "Magic 6 Board". This hands-on process allowed the girls and boys to better understand what had been previously demonstrated. The workshop also promoted teamwork and problem-solving skills, which are important skills to have if the students want to pursue a future in engineering.

On December 1st, Raphael Cordina led our second STEM Outreach workshop. "The Dancing LED Workshop" was presented to 20 middle school boys and girls. Similarly to the "Magic 6

122

Board", the students were explained the fundamentals of current and voltage, as well as taught how to use the microphone, resistors, capacitors, transistors, LEDs and switches used in the workshop. Current was visually explained with the use of a light switch. If the switch was in the off position, the students could see that the lights were off and the circuit was open, leading to no current flow. If the lights were on however, the circuit was closed and current was flowing.
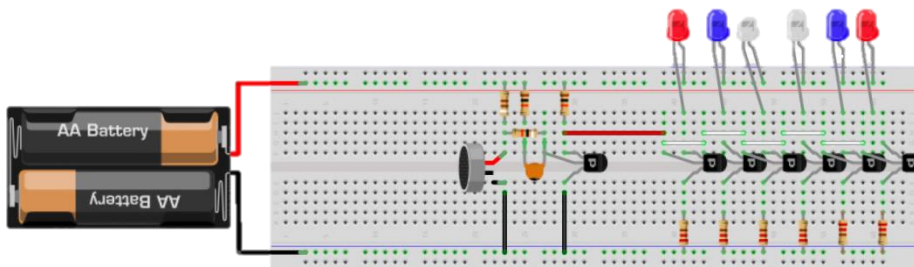


The piano workshop is one of our most popular workshops. As most of VCAT SWE's electrical workshops do, the students were taught the fundamentals of current and voltage. They were then explained the uses of the resistors and 555 timer within the piano circuit. On January 19th, Jacqueline Oricchio ran this workshop at NCC's GEAR UP Next GEN STEM Day for 40 students. The workshop combined music and engineering to create the perfect combination of interest for the middle school students that Jacqueline taught.
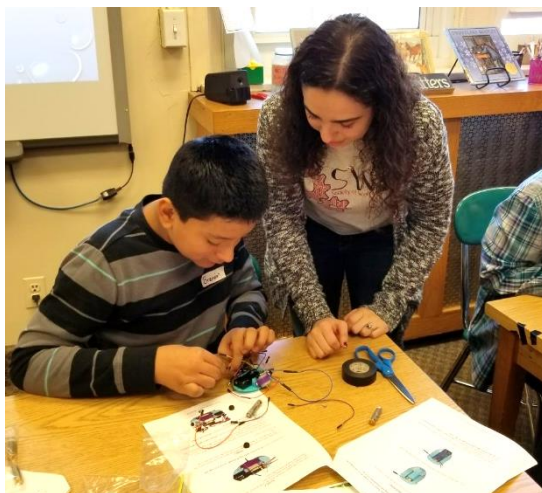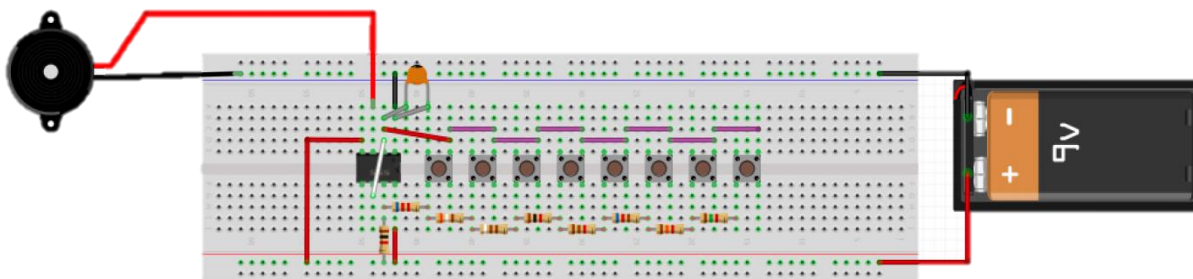




Niki Taheri was tasked with the creation of a mechanical workshop for elementary boys and girls at a local school in Elmont. The result was "The Beetle Bot Workshop", which she ran for 25 students on January 26th. She began with a presentation on motors, wires, current, and the basics of 3D printing. The students were then given explanatory packets and the opportunity to build their bots. Unlike any other workshop held by SWE, all of the 3D printed parts where printed entirely at Vaughn College. Because of this, the SWE members were able to print the Beetle Bots in a variety of colors. This allowed student creativity to blossom as it gave them the freedom to customize their bot as they pleased.

The Beetle Bot was wired in such a way that, if an antenna limit switch was pressed, the current to one of the motors stopped flowing, thus forcing all of the current to its partner motor. This meant that only one motor ran, which in turn caused a turning motion. As soon as the antenna switch was no longer pressed, the current was fed back to that once stopped motor.

**Professional Development**

In between STEM Outreach Workshops, the Society of Women Engineers spends a lot of time with the professional development of its members. This development includes workshops on resume writing, portfolio development, and cover letters. The chapter also reviews the STAR format, interview questions, and how to create an intriguing elevator pitch for recruiters. These skills are reviewed throughout the school year and help prepare VCAT-SWE members for conferences and the engineering facility tours that they arrange.

On November 17, 2017, Vaughn's Society of Women Engineers with the help of Career Services arranged for 18 students and 2 faculty members to tour RCM Technologies inc. in Shelton, Connecticut. Upon arriving to the facility, the students were taken through the offices of RCMT and given a thorough explanation of the different engineering departments within the company. They also had the opportunity to meet Vaughn alumni and hear about their experiences while in the field. Following this, the students were brought to RCM's Penthouse conference room where they were given the history of Sikorsky, had the opportunity to hear from some of the engineering managers about their industry experiences, and were enlightened on the opportunities currently available for Vaughn's engineering students.

It seemed that no matter whom the students encountered on the trip, the Engineering Managers continuously boasted about how much they loved Vaughn students. According to Harry Pember, the Vice President/ General Manager of RCM Technologies, "Vaughn students enter the aviation industry with more technical knowledge than students from many other colleges and universities we've encountered. Their CATIA knowledge is what really makes them stand out from others." The RCM trip was extremely valuable to the students. It gave them a first-hand look into the aerospace industry and their future opportunities within it. These industry visits allow for our members to grow professionally and gain valuable knowledge about different industries.

**Society of Hispanic Professional Engineers (SHPE) Club Activities**



**<u>Preparation for career</u>:** resume review and interview practice *(October 3, 2017)*

This was the second workshop to help our members and other students in improving their resume and improve their interview skills. This workshop was made for the main purpose of helping our senior students in improving their resume and the important things they need to have on their resume to make it stand out more than the others. This workshop also helped the senior student in building up their confidence and preparing them for future interviews they may get. This workshop was a success since many senior students got a better understanding on how to write a professional resume and they could build up their confidence for future interviews.

### Haunted House: *(October 20, 2017)*

For this event, SHPE collaborated with NSEB, EWB, and Women in Aviation in creating this scary theme to get more involved with the school and the theme the school had for that month. The purpose of this event was to create a haunted house to scary students. Each club was assigned a room in where they created a horror environment in where one had to scare the visitors to the next room until they reached the relaxation room in where they can relax while getting something to eat and drink, while watch a scary movie. This event was very successful since we created new connects with other clubs and learned how to collaborate with them. We learned how to communicate with one another better, as well as how to be more organized.

### "Engineer your Future" (*Mock-Interview*): *(October 21, 2017)*

For this event, SHPE collaborated with NSEB in hosting this event. This was the first attempt for our chapter in hosting a Mock-interview and having different companies come to help in improving ones resume and interview skills. The purpose of the event was to get our members and other students prepare for interviews and help them build up one's confidence. We want our members and other student to gain the experience and to create new connections with professionals. This event was very successful since we created new connects with different companies and improve one's resume and interview skills. We learned how to reach out to companies for help, as well as how to organize and host a Mock-interview

### Resume & Business Cards Building: *(October 28, 2017)*

For this event, SHPE collaborated with NSEB in creating this workshop to help our members and other students in improving their resume and teaching them how to make their own business cards. The purpose of this workshop was to prepare our members for the SHPE Nationals Conference. This workshop was successful since they learned how to develop their own business card and learned what important information they need to but in their resume so it would stand out f the or catch the attention of the employer.

**Open House 1 & 2:** *(November 11, 2017 & November 18, 2017)*

During both open houses, the school provided every club with their own table to promote and recruit more members to join their clubs. This gave our club the opportunity to reach out to upcoming students in the Vaughn Community. Our club participates in this event every semester in promoting future Vaughn students in joining the SHPE community. Our community also collaborated with other clubs to demonstrate that Vaughn Community is a safe and friendly community and that everyone is welcome.



**Homecoming Dance:** *(November 18, 2017)*

For this event, SHPE collaborated with the Music club to help host Vaughn's first ever homecoming dance. The purpose of the event was to create a homecoming dance for the students so they can come together, dance, and relax. This event was successful, since we were able to gather many students together in order to experience their prom all over again. We learned that it is sometimes good to take a break from work.

**Noche de Ciencias:** *(February 9, 2018)*

For this event, SHPE collaborated with the professional SHPE members in getting younger audience involved in STEM (*Science Technology Engineering Mathematics*) and in helping them to gain a better understanding of the STEM program. For this event one had to teach the younger audience how a circuit works, would it work if the wires were placed in liquid, and which liquid would conduct more current, in other words which will make the LED light brighter. The four liquids were used for the experiment was water, salt water, Gatorade, and orange juice. This event was a success since we could attract so many young audiences to our booth and get them involved in STEM.

**#Touchdown:**

Pre-college Students engaged in an Aeronautical Engineering Project that involves the assembly of a Landing Gear of an aircraft. In this Workshop students worked together to learn about different circuits involved in the system. Students left with a basic understanding of electrical and mechanical systems that make up for a safe landing. At the end of the workshop, students took part in a small activity that will determine which group gets to compete for the full functioning landing gear system.

**RLDC:** *(March 1-3, 2018)*

Regional Leadership Development Conferences also known as RLDC was a conference in where all the region 4 SHPE members gather together to network with one another and with many different companies. The purpose of this conference was to help our fellow SHPE members in networking with others, building up ones' confidence, and improving ones resume and elevator speech. This conference helped develop ones' confidence and build up their connections. This event also had many workshops to help improve one's leadership skills, communication skills, etc. This conference was a great learning experience to many of our fellow members in preparing them for the National Conference. In this Conference SHPE-VC was awarded the Blue-chip award. An award that recognizes the chapter nationally for the hard work and dedication the chapter has demonstrated since the beginning of the academic year. This is a great accomplishment for allowing Vaughn College SHPE chapter to come victorious once more as we shine among the crowd.

Engineers Without Borders-USA is a national organization that works to create a better world through engineering projects which empower communities to meet their basic needs. The Vaughn College Chapter is equipping the engineering leaders of tomorrow by finding solutions to the developing world's most pressing issue, water security. The Vaughn Chapter was founded in November 2015 and has celebrated many milestones this year.



## Fundraising

On October 20th, 2017, EWB hosted their first Haunted House at Vaughn. It was a fundraising event as well as a team building activity. It welcomed creativity and a sense of camaraderie amongst all the members as well as across other organizations that participated including Alpha Phi Delta and Women in Aviation. Additionally, EWB Vaughn hosted their second annual Burritos Without Borders fundraiser which partnered with Chipotle.

## Habitat for Humanity

On November 3rd, 2017, the Chapter chose to impact their local community by volunteering through Habitat for Humanity. Habitat for Humanity purchases abandoned houses from the city for $1, and renovates them through volunteers. The homes are sold to low-income families for a below-market mortgage. The EWB Vaughn members learned necessary skills to renovate a house. Attendees assembled and installed metal frames for drywall



installation in the basement, installed sheetrock in a bathroom, fixed the floors of the attic, and managed some insulation issues. Back by popular demand, on March 9th, 2018, the Chapter partnered with the Vaughn Veterans Organization to volunteer once again. This time, the team worked on a house in its final stages. The finishing touches were put on a home in Jamaica, Queens. The team learned caulking and painting techniques. The Chapter plans to continue volunteering with Habitat for Humanity.

129
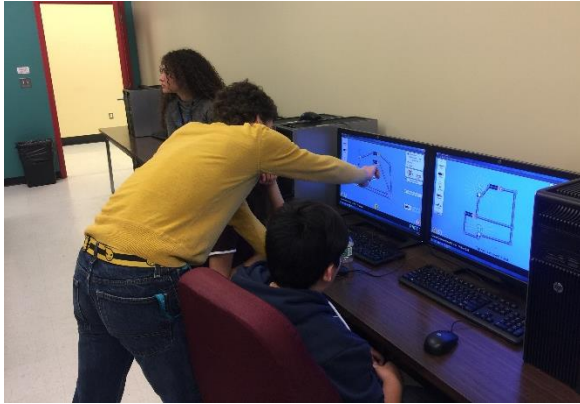
**STEM Outreach: Conductive Paint Workshop**

On January 19th, 2018, EWB hosted a STEM outreach project during which middle school children were taught how to design and build their own circuits using conductive paint. The students also learned about conductivity and resistance by mixing graphite powder and acrylic paint to make their own conductive paint. Interacting with the future generation of engineers and creative minds was rewarding. It also provided management experience and fostered team bonding.

**Professional Development Networking Workshop**

To increase their professional skills, on February 8th, 2018, team members gathered for the Networking workshop. The session focused on presentation, public speaking tips, and communicating passion. Attendees practiced their elevator pitches amongst the group to prepare for upcoming conferences during which networking skills are paramount.

**University of Connecticut Mini Conference**



On Saturday, February 10th, members travelled to the University of Connecticut in Hartford. During the one-day conference, the Vaughn chapter attended breakout sessions about water testing practices, recruitment, web design, using drones for land mapping and surveying, and more. The students used to opportunity to expand their network and obtain invaluable advice from other chapters about starting their first international community application.

**NYC Area Mini Conference**

Soon after on February 24th, 2018, the chapter travelled to Fordham University to participate in the NYC Area Mini Conference. This day was exciting and filled with accomplishment. The Chapter's very own Fundraising Director, Sophomore Hermes Rosario, was featured on the Fundraising Panel. Additionally, all attendees participated in roundtable discussions about member retention, chapter structure and leadership, corporate outreach and networking, domestic outreach, roadblocks in international development, staying involved after graduation, and more. Finally, through networking the chapter welcomed two new professional mentors to their team, Patrick Farnham and Walt Walker. The mentors will guide the chapter in technical design while overcoming cultural barriers to choose appropriate technologies.

**Future Goals**

EWB Vaughn's central goal is to partner with a community in the developing world to implement a solution to water insecurity. This year under the determined leadership of Project Lead, Jamal Sharifi, members have tirelessly researched potential international community programs. EWB members are bonded by an undeniable passion to partner with and empower a community in need. Through weekly mentor conference calls, countless emails to NGOs and other partner organizations, and travel risk management, the Chapter is closer than ever to achieving this goal.



**A Special Thanks**

EWB wants to thank US Didactic for its support. Your contribution is greatly appreciated. EWB aims to exceed your expectations, and look forward to working with you in the future. EWB also wants to thank Dr. Rahemi and Dr. LaVergne for helping obtain funding for two desktop computers. Installed in the EWB Room in February 2018, the computers provide access to invaluable software and collaborative opportunities. Finally, the Chapter thanks Dr. Sharon DeVivo for her perpetual support and encouragement.

## National Science Foundation Grant

The National Science Foundation (NSF) awarded Vaughn College with Scholarships in Science Technology Engineering and Mathematics program (S-STEM) grant (Award #: 1154000; Years: 2012-2018) for the total amount of $575,000. The focus of the *Scholarship Increasing Student Enrollment and Achievement in Engineering and Engineering Technology* is to provide students with the necessary financial support and access to faculty mentors and industry professionals necessary to further their technical and academic skills while increasing their readiness for placement in the engineering technology workforce. By exposing scholarship recipients to engineering learning communities, faculty mentorships, after class professional robotics, UAV and automotive club activities, industry internships, and industry connection seminars, Vaughn enhances the overall academic experience for these students. The combination of these activities in conjunction with academic support services provides the scholarship recipients with the skills necessary for the successful completion of their degrees.

The S-STEM program fostered a sense of community among the scholarship recipients. During each year of the program, various social gatherings were organized for the scholarship recipients where they interacted with fellow participants, faculty mentors, tutors and College administrators. The College's engineering and technology department also organized an annual Technology Day conference where recipients presented their S-STEM projects to their peers, members of the College's Industry Advisory Council and faculty mentors at the NSF poster session on Technology Day. Students posters are evaluated by Industry Advisory Council members and the top two posters are selected by our Industry Advisory members as the recipients of the best poster awards of this session. Advisory members are encouraged to give recipients feedback and suggestions about their presentations. These experiences afforded the scholarship recipients the opportunity to further their technical and academic skills while increasing their readiness for placement in the technology workforce or for continuation of their education at the graduate level.

For the past five years, as a result of the NSF scholarship, students have been to participate in several in-class and out-of-class learning communities which fulfill the NSF STEM project objectives and outcomes. The NSF-supported learning communities enhanced learning outcomes related to hands-on experience and problem solving, programming, teamwork and communication skills, thus and providing participants with a greater appreciation for engineering education. As a result of these NSF-supported learning communities, our scholarship recipients were able to participate in many regional, national, and international conferences and paper and poster sessions. These communities also enabled student participation in robotics and UAV competitions. Below is a list of Vaughn's S-STEM conference participation, as well as Vaughn's scholarly and technical accomplishments.

1. Four NSF scholars presented their NSF projects (Project 1. **Design and Implementation of a Braille clock** and Project 2. **A low Cost Automated Pill Dispenser for Home Use by**) during the Maker Event session of ASEE Annual Conference in in New Orleans, Louisiana, June 26-29, 2016. Their projects were selected as finalists for the ASEE Design and Manufacturing division competition. The student project entitled "**Design and Implementation of a Braille clock**" by Saneela Rabbani and Josiah D'Arrigo

received the **2<sup>nd</sup> place award of 2016 ASEE Manufacturing Student Division Competition**.

2. Three NSF scholarship recipients along with other team members participated in the 2016 VEX U World Championship Competition in Louisville, Kentucky Freedom Expo Center. From April 20-23, among the fifty nine national and international universities and colleges invited to the 2016 VEX U World Championship, **Vaughn's team finished first, winning the Innovate award, Design award, and the Design Division tournament championship, ultimately becoming the VEX U World Tournament Champions.**

3. Four NSF scholars' projects were accepted and they participated as finalists in the autonomous category of the American Helicopter Society (AHS) International's Annual Micro Air Vehicle (MAV) competition on May 16, 2016, at West Palm Beach Convention Center, Florida.

4. Since 2015, NSF scholars from Vaughn's Robotics and UAV club participated in **Vaughn's Annual Manufacturing Day Conference** (October of each year) and hosted several STEM workshops on Robotics and programming, learning how to build a drone along with a drone flying session in Vaughn's hangar.

5. From 2016 to the present, several NSF scholars from Vaughn's UAV club assisted the Cradle of Aviation Museum with a UAV workshop and competition for middle school and high school students.

6. Since 2016, NSF scholars planned, developed, and organized a day of drone workshops related to Arduino Programming, CAD Modeling of Quadcopters, and Learn to Build a Drone to celebrate **International Drone day** (May of each year). The event allows participants (visitors and students) to design, build, and test their own drones in the netted flying arena in the college hangar.

7. The NSF scholars' project of Vaughn's UAV team was accepted and these scholars participated as finalists beside Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University in 5<sup>th</sup> annual AHS Micro Air Vehicle (MAV) student challenge competition in Dallas Fort Worth Convention Center on May 8, 2017. Vaughn's UAV team successfully completed the task and won the **2<sup>nd</sup> place award** of this challenging competition.

**8.** Two NSF scholars' research project "**Volumetric Flow Visualization using continuous wave Laser and Scanning Mirrors.**" was accepted and presented during a maker event session at 2017 ASEE Annual Conference on June 27, 2017 at Columbus, Ohio. Among twenty participating teams, Vaughn's student paper won the **"Innovation Award"** of the manufacturing division's "Make It" session of the conference.

9. For the past several years, Vaughn NSF scholar projects have been accepted, presented, and published in the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) Conference. In 2015, 2016, and 2017 they received top ranking at both paper and poster student session competitions.

In addition to the above accomplishments, many of Vaughn's NSF scholars participated in many other regional conferences and competitions in which they finished successfully and received top ranking. The student engagement section of the VCJET provides more details on these student activities and accomplishments.

NSF Scholars Involvement in Scholarly Activities-Student Paper and Poster Competitions



NSF Scholars Involvement in STEM Workshops and Competitions

**HIS-STEM Title III grant**

Through "Developing Guided Articulated Completion Pathways in Leading Edge Aeronautics and Aviation Careers for Hispanic and Low-Income Students" Vaughn College continues to develop a much needed pathway for Hispanic students to increase their access into the College's engineering degree programs. Project goals include:

Vaughn has made progress on its project goals which include:

1. Close <u>academic achievement gaps</u> where students are at high risk of failure or withdrawal, including increasing the percentage of Hispanic and low-income students who participate in grant-supported services or programs and who successfully complete gateway courses, and increase the percentage of Hispanic and low-income students who participate in grant-supported services or programs and who are in good academic standing

2. Expand focus on <u>persistence</u> to include the development or redesign of instructional programs and support strategies that facilitate Hispanic and low-income student transition through upper division studies in high demand STEM fields.

**3.** Strengthen <u>college capacity</u> for offering opportunity equity for all students, through stronger outreach to high school and community college students.

**Progress Summary:**

We are very pleased with the significant progress made toward meeting overall goals and objectives including steady increases in enrollment in STEM related programs. The Engineering and Technology department is making significant progress toward implementation of those goals. Below are current activities the College is implementing to attain those goals:

➢ Supplemental Instruction (SI) is a student academic assistance program that increases academic performance and retention through the use of collaborative learning strategies. The SI program at Vaughn targets challenging mathematics, engineering, and physics courses and provides regularly scheduled, out-of-class, peer-facilitated sessions that provide students with the opportunity to process the information learned in class. Supplemental instruction is a proactive approach to student learning and engagement which increases student persistence and retention (**attaining goals 1 & 2**).

Vaughn began its SI program under the Broadening the Gateway to 21st Century Engineering Degrees for Under-served Hispanic Students Title III grant (P031C110012). The student supplemental instructor is assigned the task of reviewing class lectures, conducting problem solving sessions and communicating with the faculty members about the areas where students need reinforcement in order to be successful in the course.
The College's current Title III grant (P031C160021) provides necessary support to further develop and expand the SI program in order to improve student learning outcomes and to prepare students for the core courses within all engineering and engineering

135

technology programs. Under the College's new Title III grant, Vaughn hired two writing specialists, in Vaughn's Teaching and Learning Center (TLC) to assist students with their capstone degree projects, technical writing and presentation. As a result of this program, some of our students' research projects were accepted for publication and presentation in technical conferences such as the annual conferences of the American Society of Engineering Education, the Society of Women Engineers, the Latin American and Caribbean Consortium of Engineering Institutions, the Institute of Electrical and Electronics Engineers, the Society for Experimental Mechanics, and the American Society of Mechanical Engineers.

➢ In 2016, the new Title III HSI-STEM grant provided necessary support to engage students in robotics and UAV activities and competitions. Also, students in both groups mentored many high school students by organizing workshops and assisting them in hosting their own robotics and drone competitions. Vaughn's UAV team assisted Cradle of Aviation Museum in developing and hosting drone games and competitions for high school students. High school department chairs attended some of those events to increase awareness about Vaughn's engineering programs (attaining goal 3-outreach).

➢ Dr. Rahemi, with the assistance of the STEM pathway liaison and articulation coordinator, established the following program articulation agreements with two years institutions. These articulation agreements will allow students who completed their associate degree program in engineering science to continue in Vaughn's BS Mechatronic, Mechanical, and Electrical engineering programs.
   1. Mechanical and Mechatronics engineering agreements with BMCC's Engineering Science program (Dec 2, 2017).
   2. Mechanical and Mechatronic Engineering agreements with Bergen's Engineering Science program (Nov 9, 2017).
   3. Mechanical and Mechatronic Engineering agreements with Nassau's Engineering Science program (Nov 9, 2017).

Currently, the following program articulation agreements are in the process of completion.

   1. Electrical Engineering agreement with Bergen's Engineering Science program
   2. Engineering programs agreements with Robert F. Kennedy Community High school. As part of this agreement, RFK's junior and senior level students can enroll for **Introduction to Robotics, MCE101,** 1 credit (three contact hours) at Vaughn College. Upon successful completion with a grade of C or better, this course can be applied towards a Vaughn College Engineering Program degree.

➢ During summer 2017, both Dr. Budhoo, composite prototype curriculum designer, and Prof. Jesus, 3D/CNC Designer, attended several hands-on training courses related to composite manufacturing, design, CNC machining, and 3D additive Manufacturing. These training courses helped the grant management team with valuable lessons in the development process of facilities and laboratory equipment that will allow Vaughn to provide practical STEM hands-on training in composite and additive manufacturing, current with today's industry demands.

- **Stackable Certificate Programs:** In fall 2017, the grant management team completed the following manufacturing certificate programs and received NYSED approval of these certificates.

    1. Composite Manufacturing Certificate Program – In mid-October, the grant management team completed an application for a composite manufacturing certificate program which was submitted to the NY State Education Department for review and approval. In mid-November we recived an approval from the NYSED regarding this certificate program. The department will begin to offer courses within this certificate program after completion of the composite laboratory renovation and the purchase of supporting equipment.

    2. **Computer Aided Design for Additive and Subtractive Manufacturing Certificate Program**: In early November, the Project Director with the assistance of the Grant Management team, completed an application for a 3D Additive and Subtractive Manufacturing Certificate program which was submitted to the NY State Education Department for review and approval. In mid-December, we recived an approval from the NYSED regarding this certificate program.

  Currently PD are working with the grant management team to develop three more certificate programs in CNC machining, PLC and automation, and UAS.
- **BS in Advanced Manufacturing:** The Manufacturing Curriculum Committee is developing a new Advanced Manufacturing Engineering Technology program to introduce students to practical hands-on manufacturing skills. Students of this program will acquire knowledge in the area of Computer-Aided Design and 3D Printing, Computer-Aided Manufacturing and Prismatic Machining, Composite Manufacturing and repair process, CATIA Composite Product Design, CNC Machining, and UAV construction and applications. Students in this field are required to take courses in basic engineering sciences and application (applied statics & strength of materials, applied thermos-fluid, and mechanical testing) to further enhance their understanding of the advanced manufacturing process. To complete this program, students are required to take 3 credit hours of a senior manufacturing capstone project. The first draft of this program will be introduced to our Industry Advisory Council members during Vaughn's annual Technology Day Conference.
- **Laboratory Development:** Currently, the Engineering and Technology Department is in process to establish three new state-of-the-art laboratories: 3D Prototyping Innovation Center, Composite Manufacturing Center, and CNC Machine Shop. These centers are needed to support current engineering programs as well as to establish a new advanced manufacturing program. Meetings were held to discuss the status of the CNC and composite labs development. Both Dr. Yougashwar Budhoo, Composite Prototype Curriculum Designer and Professor Manuel Jesus, 3D/CNC Designer who attended several summer's composite and additive manufacturing training courses, determined that we would require additional laboratory equipment related to Instron material test system (tensile tester), oven (for curing composite layup), Autoclave, ply cutting table, two hot bonders, five Vacuum bagging kits, two vacuum pump and accessories, supplies for composite manufacturing (resin, fabric, tapes, films, peel ply), Desktop Metal 3D Printer, coordinate measuring machine (CMM) and automation subsystem and system

137

PLC training. This laboratory equipment will allow Vaughn to provide students with practical STEM hands-on training in composite and additive manufacturing that is current with today's manufacturing industry demands. The program will purchase some of this equipment by the end of this academic year.

**Students' accomplishments and success:** Below is a list of student accomplishments that are a direct result of the current HSI STEM grant and its implementation process:

1. The Vaughn College robotics team participated in numerous local, state, and world championship events, winning or placing high in all of them. Vaughn's robotics team has been a great outreach tool to increase engineering student retention and success.

   - Vaughn's robotics team received 3$^{rd}$ ranking in the Innovate division of the 2017 world championship, out of sixty participating teams.
   - The Vaughn College Robotics team, one of the top three competitors in the 2017 VEX U Robotics world championship, was invited to participate in Mexico's VEX U Reeduca Robotics competition in in the American School of Tampico, Tamaulipas, Mexico. Vaughn's robotics team members consistently demonstrated persistence and drive in order to retain their title as champions of Mexico's VEX U Robotics competitions for three years in a row.
   - Vaughn College hosted VEX U Robotics Regional Qualifier on Saturday January 27, 2018. Vaughn's Robotics Team (VCAT) won the 2018 VEX U regional Skill Challenge and Tournament Champion Awards and qualification to participate in the 2018 VEX U World Robotics Championship
   - Vaughn College participated in the 2018 West Virginia VEX U Robotics Regional Qualifier Competition on Friday March 2, 2018.
   - VCAT2 won both "Finalist" and "Robot Skills" championship awards thus qualifying the VCAT2 team to participate in the 2018 VEX U world championship.
   - Outreach Activities:
     - ✓ PD, Faculty, and Vaughn's Robotics team assisted Vaughn College in hosting its fourth annual state qualifier high school robotics competition on Saturday January 13$^{th}$, 2018. A total of 37 regional high schools from Queens, Brooklyn, Bronx, Nassau, and Suffolk County attended the January VEX state qualifier at Vaughn College.
     - ✓ Vaughn's Robotics team assisted Farmingdale High School in hosting their regional high school robotics competition on Sunday Jan 7, 2018.
     - ✓ PD, Faculty, and Vaughn's Robotics team assisted Freeport High School in hosting their regional high school robotics competition on Saturday Feb 3$^{rd}$, 2018.
     - ✓ Vaughn's Robotics team hosted Robotics workshops for High School students (Freeport, Bayside, Garden City, and South Country school districts, as well as from The Wheatley School and Thomas Edison

high schools) during Vaughn's Annual Manufacturing Day conference on Friday, Oct 27, 2017.

✓ Vaughn's Robotics team hosted Robotics workshops for High School students during Vaughn's Annual International Drone Day On Saturday May 6, 2017.

2. Since 2016, the Vaughn College UAV team participated in the Micro Air Vehicle completion of the American Helicopter Society (AHS) Conference, winning top place in the MAV student challenge completion.

- Vaughn's UAV team project was selected as one of the finalists in the 4th annual Micro Air Vehicle (MAV) student challenge competition at West Palm Beach Convention Center on May 16, 2016.
- Vaughn's UAV team project was selected as one of the finalists along with Georgia Tech, Penn State, North Dakota State University, University of Maryland, and Concordia University to participate in the 5th annual Micro Air Vehicle (MAV) student challenge competition at Dallas Fort Worth Convention Center on May 8, 2017. Vaughn's UAV team won the 2nd place award of this competition, a $1,000 check.
- Outreach Activities:
  ✓ Since 2016, Vaughn's UAV team assisted the **Cradle of Aviation** Museum with UAV workshops and competitions for middle school and high school students.
  ✓ Since 2015, Vaughn's UAV team hosted several STEM workshops on learning how to build a drone, along with a drone flying session, for High School students in the Vaughn hangar, during **Vaughn's Annual Manufacturing Day conference**.
  ✓ Since 2016, Vaughn's UAV team organized a day of drone workshops related to Arduino Programming, CAD Modeling of Quadcopters, and Learn to Build a Drone to celebrate **International Drone day.**

An addition to the above accomplishments, as a result of HSI STEM grant, many of Vaughn's students were able to participate in scholarly activities and student paper and poster sessions of regional, national and international conferences and competitions (ASEE, LACCEI, SWE, ASME, SHPE, and IEEE), and receive top ranking in those events. The HSI STEM grant also provided necessary funding support for clubs such as SWE, EWB, SHPE, and NSBE to participate in professional development, and the organization of STEM related workshops at Vaughn College. The student engagement section of the VCJET provides more details on those activities and on student success and accomplishments.

**List of 2016-2017 Placement Activity**

The following table provides graduates' career placement statistics within the engineering and technology department for the 2016-2017 calendar years. This can be used as an indicator to evaluate the effectiveness of the program in producing graduates who are sought by the general engineering industry and graduate schools. During the academic year 2016-2017, our students obtained internships and accepted employment at several corporations, including Boeing, Daimler, Sikorsky Aircraft, Toyota, Cummins, Pratt and Whiney, John Deere, RCM Technology, FAA, Safe Flight Instruments, Cox & Company, Cyient, and many others. These corporations have employed our graduates as mechanical engineers, design engineers, mechatronics engineers, control engineers, structural engineers, avionics engineers, and project engineers. The department of engineering and technology views such placements as a strong indicator of our students' value to the industry and of our programs' success in meeting our objectives.

| Student Name | Program | Internship | Industry | Graduate School |
|---|---|---|---|---|
| Eric Grieco | Mechatronic Eng. | Precise LED Summer 2017 | | |
| Niki Taheri | Mechatronic Eng. | Con Edison – Sum 2017 | | |
| Milana Natanova | Mechatronic Eng. | | Cyient – April 2017 | |
| Monica Vantepool | Mechatronic Eng. | Toyota-Spring 2016 | Toyota – May 2017 | |
| Daniel Khodos | Mechatronic Eng. | SciMax Tech, Sum 2016 Rolls-Royce, Sum 2017 | | |
| Dimitri Papazoglou | Mechatronic Eng. | DOE, Pacific Northwest National Laboratory-Summer 2016 | | MS in EE U. of Dayton |
| Emily German | Mechatronic Eng. | Daimler Summer 2017 | Daimler, May 2018 | |
| Betsy Sanchez | Mechatronic Eng. | Toyota-Spring 2017 | Cummins, May 2017 | |
| Lovedeep Kaur | Mechatronic Eng. | John Deere-Summer 2017 | Lockheed Martin, Sikorsky Aircraft, May 2018 | |
| Olivia Hyman | Mechatronic Eng. | NASA-MUREP, 2014-16 Ames Research Center, Mountain View, CA | | |
| Eric Griaco | Mechatronic Eng. | Precise LED Inc Summer 2017 | | |
| Saneela Rabbani | Mechatronic Eng. | Pall Corp., Fall 2015 DOE, ORNL Summer 2016 | Wunderlich-Malec, May 17 | |
| Bobby Tang | Mechatronic Eng. | | | MS In Mechatronic NYU |
| Jason Becker | Mechatronic Eng. | EJ Electric - Sum 2017 | | |
| Josiah D'Arrigo | Mechatronic Eng. | Alken Industries, 2015 DOE-ORNL, Summer 2016 | Underwriters Laboratories (UL LLC.) - 2016 | |
| Waseem Hussain | Mechatronic Eng. | Union Crate, 2015-17 | Co-Founder & VP of Union Crate | |
| Jacqueline Oricchio | Mechatronic Eng. | Rolls-Royce, Sum 2018 | | |
| Hector Sabillon | Mechatronic Eng. | John Deere-Summer 2018 | | |
| Ahmed Elshabrawy | Mechatronic Eng. | | Boeing - PLC Manufacturing Line 2018 | |
| Dana Mathura | MET | | Cyient – August 2017 | |

| Name | Program | Internship | Employment | |
|---|---|---|---|---|
| Aye Thet | MET | | Cyient – August 2017 | |
| Eulissa Lora | MET | | Cyient – August 2017 | |
| Sayhat M. Karca | ME | Magellan Aerospace Sum 2017 | | |
| Mostafa Aboali | ME | | Boeing-The wiring Integration Design – Spring 2018 | |
| Nicolas F Ceballos | ME | SciMax Technologies | Lockheed Martin, Sikorsky Aircraft, Dec 2018 | |
| Brandon Duran | ME | Hudson Technology – Summer 2017 & 2018 | | |
| Muhammad Noman | MET | Lockheed Martin, Sikorsky Aircraft, 2016-2017 | Lockheed Martin, Sikorsky Aircraft, May 2017 | |
| Grace Davis | MET | Daimler Summer 2018 | | |
| Jessica Jemenz | MET | Raytheon – Summer 2017 | Raytheon | |
| Darwing E. Mota | MET | Exelon – Summer 2017 Gulfstream, Summer 2018 | | |
| Damian Gaona | ME | Composite Prototyping Center (CPC) | SciMax Technologies May 2017 | |
| Syed Hassan Moosavi | EET | | Bombardier – Avionics Test Engineer - 2017 | |
| Cristian Espinal | EET | | JetBlue – Maintenance Scheduling - 2017 | |
| Bryan Lucas | EET | | JetBlue – Avionics Maintenance - 2017 | |
| Shixin Nie | EET | | Panasonic Avionics - 2017 | |
| Arun Sarjoo | EET | | DEA - 2017 | |
| Mohammad Furqan | EET | | Bombardier – Avionics Test Engineer - 2017 | |
| Yuriana Leone | EET | | SafeFlight Instruments - 2017 | |
| Matthew Hanson | EET | | FAA Technical Operations - 2017 | |
| Reynaldo Francis | EET | | FAA Technical Operations - 2018 | |
| Devendra Singh | EET | | FAA Technical Operations - 2018 | |
| Marvin Guzman | EET | | FAA Technical Operations - 2018 | |
| Lily Alexander | EET | | FAA Air Traffic Control - 2018 | |
| | | | | |

# FSAE Chassis Design

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## ABSTRACT

This team is now creating the first chapter of the Formula SAE Club at Vaughn College. Universities from across the country and around the world participate in the Formula SAE interscholastic racing competition. In accordance with rules published by SAE International, students employ their creativity and engineering skills to design, build, and race a vehicle. Students are encouraged to apply their engineering ideas and theories to the entire design of the vehicle. This project aims to provide a chassis for the initial startup of the FSAE Club at Vaughn College of Aeronautics and Technology. The design will be engineered and manufactured, in accordance with the Formula SAE rules and regulations manual [1].

## 1. INTRODUCTION

The above-mentioned team will be developing the 2017 first chassis design for Vaughn College of Aeronautics and Technology. Our project will explore the overall design process for a

Formula SAE, as well as the challenges in founding a club that will become a lasting tradition at Vaughn College. Several factors will have to be considered, including vehicle dynamics, chassis rigidity, component packaging, overall manufacturing, and perceived performance. This project will be split into several phases. Those phases are initial design, computer drafting, finite element analysis, manufacturing, and verification of design. The chassis will be designed using Computer Aided Drafted software (CATIA and SOLIDWORKS) and will be analyzed using the finite element analysis feature in CATIA. The design that our team is planning to use is a steel frame chassis in a ladder configuration. The overall design of the chassis will be a space frame structure that is standard in the FSAE racing world. This design has a relatively low cost, can be manufactured with conventional tools, and is easily repaired and modified. This design also has a low strength/weight ratio meaning a slightly heavier structure. Figure 1 is the conceptual design of the entire car.
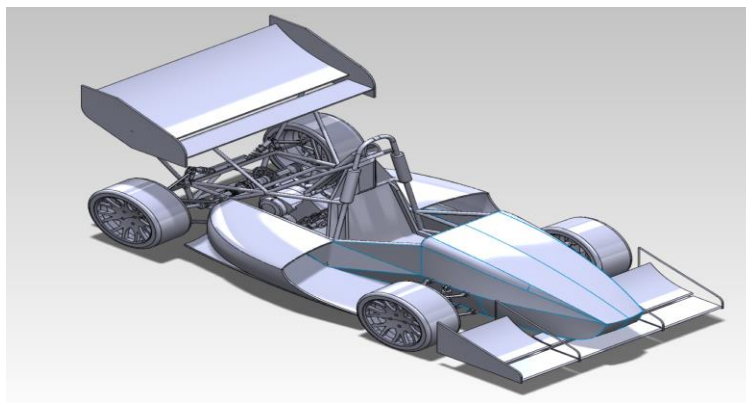


**Figure 1: Conceptual Design**

## 2. ENGINEERING REQUIREMENTS

[i] For the purpose of the competition, students are to assume that a manufacturing company has given them a contract to produce a prototype car for evaluation as a production item. Our project focus is on the Formula category, which is the weekend racer for the non-professional car enthusiast.

[ii] The majority of the regulations are based on safety factors. Cars must have two steel roll hoops bent as a single piece of 1.0-inch (25.4 mm) diameter, and internal 0.095-inch (2.4 mm) thickness for a steel alloy, regardless of the composition of the rest of the chassis. The weight is not restricted; however, the average weight of the whole race-car over the years has been 440 pounds.

[iii] The engine must be four strokes; Otto-cycle piston engine with a displacement restricted to 710cc. Node-to-Node triangulation is required for connecting different members. For the driver requirement, the chassis must be designed after a 95th percentile male template provided by the SAE rule book. The driver's head must be two inches from the top of the main hoop going down to the front hoop. Figure 2 shows how the side impact structure should be properly triangulated to produce a safe structure. Another criterion is that the driver's head must be 2 inches from the top of the Main Hoop; Figure 3 depicts this clearly.
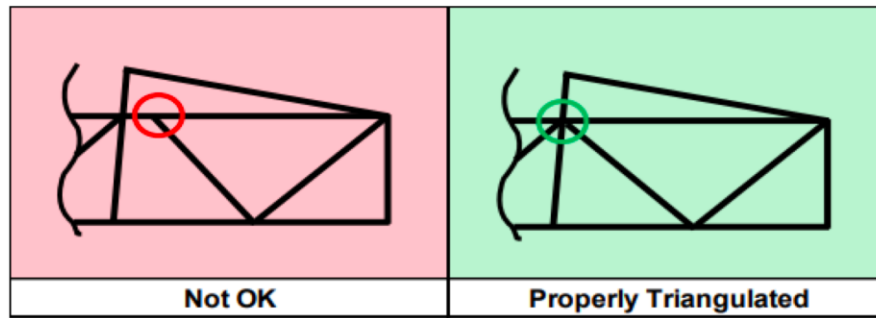
**Figure 2: Node-to-Node Triangulation**



50 mm (2 inch) Minimum to
ALL drivers and 95ᵗʰ
percentile template
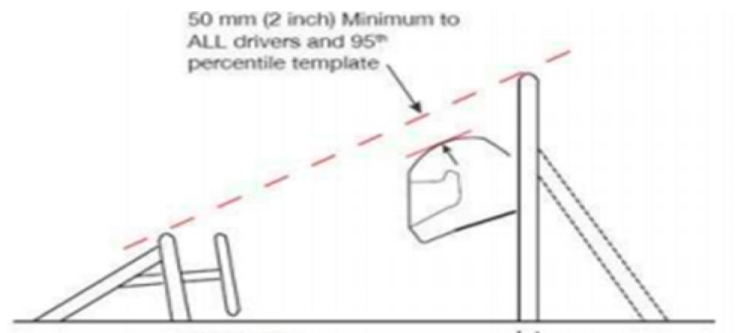
**Figure 3: Head Clearance from Top of Main Hoop**

## 3. DESIGN CONCEPT

The vehicle chassis is broken down into different sections. The front of the chassis is called the Front Bulkhead leading into the Front Hoop with Front Hoop bracings. These are attached to the Side Impact structure which is connected to the Main Hoop. The Main Hoop is then supported



Helmet must not
be rearwards
of this line when
only forward
main hoop
bracing used
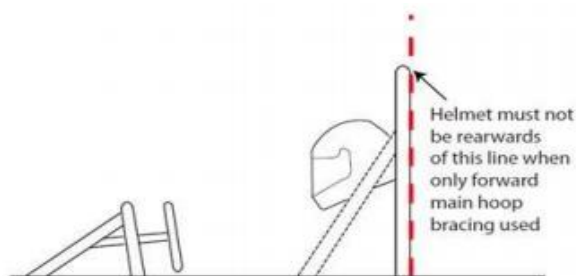
**Figure 4: Main Hoop Bracing Regulations**

by a Main Hoop Bracing structure. The only regulation for structural members is that the side impact structure must have at least three members, and the Main hoop Bracing can brace either b the back of the main hoop, the font or both [1]. If the bracing is put in the front of the main hoop, then the driver's head cannot sit rearwards of the main hoop, a configuration depicted in figure 4.

144

## 4. VEHICLE DYNAMICS

During a race, the chassis will experience certain loads; these loads will be due to acceleration, braking and turning. The forces are organized into five physical principles, kinetic energy, centrifugal force, inertia, friction and traction [3]. Figure 5 is a visual depiction of all possible forces acting on the vehicle at all times.
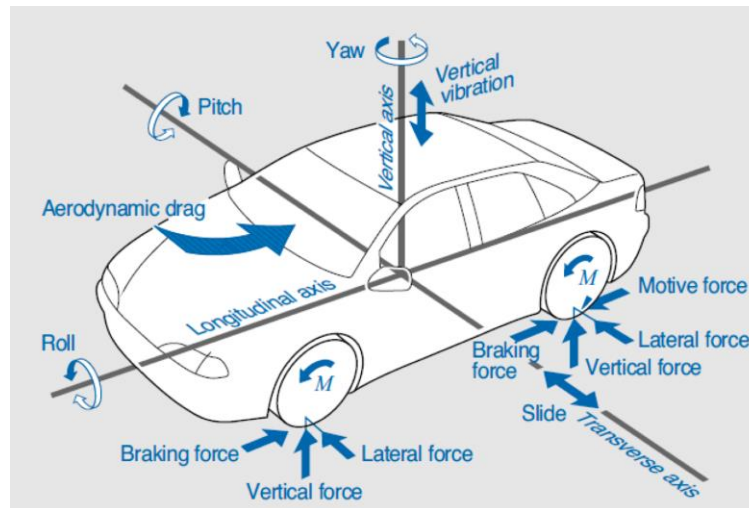


**Figure 5: Dynamic Forces**

*Initial Concept Design*

Based on our understanding of the limitations and necessary criteria, we created the initial mockup of our chassis design.
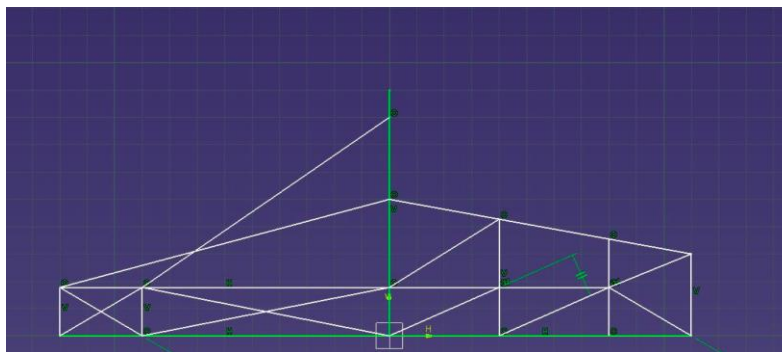


**Figure 6: Initial Design**

Figure 6 is the initial design that we later modified based on our research of the space frame chassis designs produced at other universities. The initial design was created as space frame structure, but since the bottom of the chassis was unaligned, this fact made it hard to replicate on the CAD software. In the new design, most of the sketch remained the same, but the bottom was straightly aligned. We also removed four members in order to reduce the weight, while yet

145

retaining the design's structural integrity.  We adjusted the main hoop, so that in the event of a roll-over, the driver would not make impact with the ground.
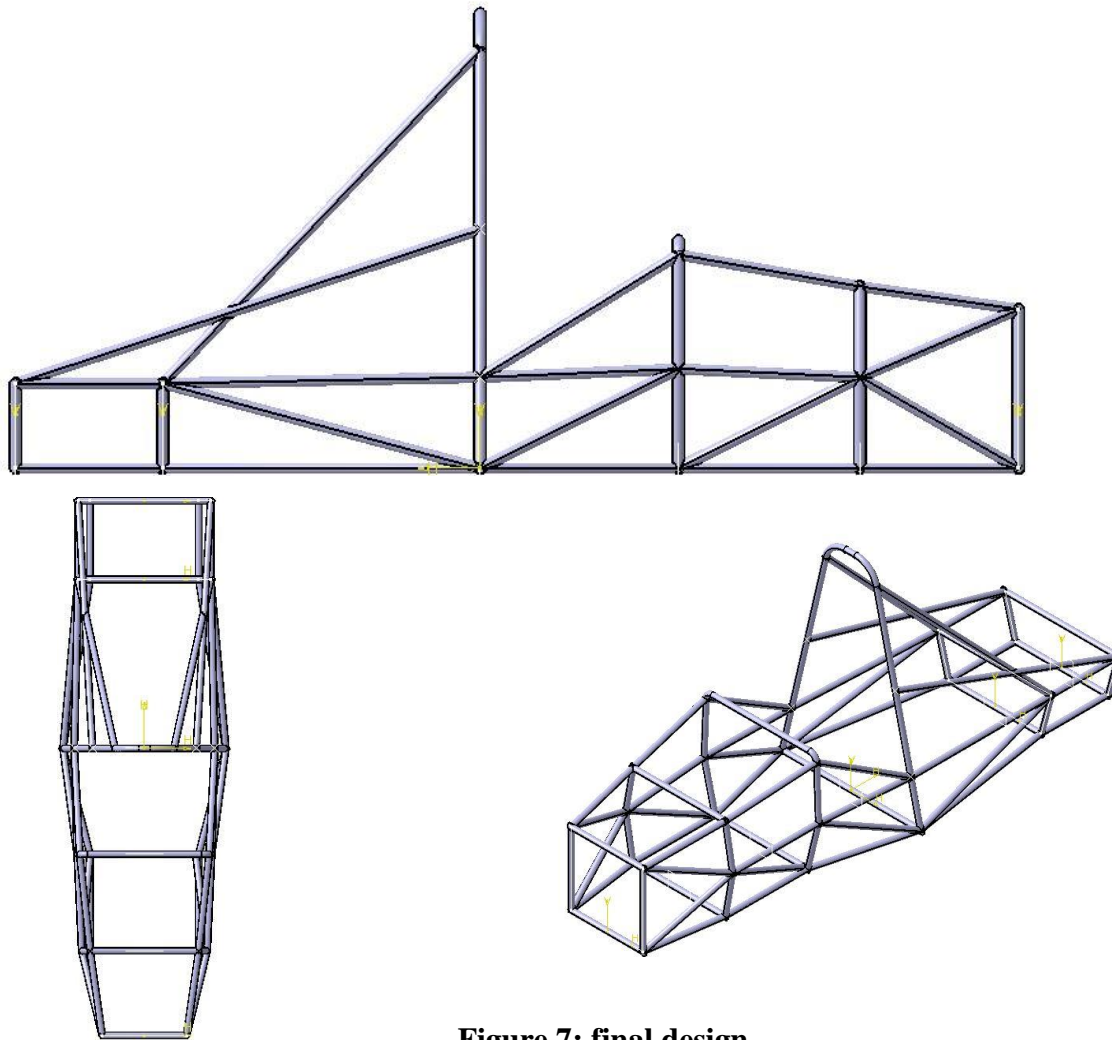


**Figure 7: final design**

## 5.  ANALYSIS

### (i) Theoretical Analysis

 The chassis of the car directly experiences includes two types of loading:  dead loads and live loads. Dead loads include the seat, engine, and the suspension system. The live loads include the drag force due to the spoiler, as it changes based on the way the car is moving; drag force is high around the corners and when the car is braking. This design increases stability and allows for speed around corners. The other live load is the driver; because multiple drivers in each team participate in the Formula SAE competition, their weights may differ, thus changing the load with each driver. The force experienced by the car as it travels around a corner at 30 mph is calculated as follows:

## Cornering Forces

*Circular Acceleration*

$$a = \frac{V^2}{R} \tag{1}$$

*Tangential Acceleration*

$$a_t = \frac{V_f - V_i}{\Delta t} \tag{2}$$

Car=600 lbs

Average Velocity= 30 mph

Mass=$\frac{w}{g} = \frac{600\ lbs}{32.2\frac{ft}{s^2}} = 180\ slugs$   $V_i = 30\ mph\ (44\frac{ft}{s})$   $V_f = 10\ mph\ (14.67\frac{ft}{s})$

$a_t = 32\frac{ft}{s^2} = \frac{14.67-44}{\Delta t} = .9167\ sec$   $\Sigma F_t = ma_t = 180\ slugs * 32\frac{ft}{s^2} = 576\ lbf$

$\Sigma F_n = ma_n = m\frac{v^2}{R} = 18\ slugs *(\frac{14.67\frac{ft}{s^2}}{25.0164\ ft}) = 157.785 lbf$   (3)

F=$\sqrt{F_t^2 + F_n^2} = \sqrt{576\ lbf^2 + 154.785 lbf^2} = 596.435 lbf$   (4)

## For front impact collision:

During front impact, the maximum force experienced by the chassis is as follows; these values are used as input into CATIA FEA to analyze the chassis and to select the appropriate size of the members.

$$v_{f^2} = v_{i^2} + 2a\ (x) \tag{5}$$

Where:

x = 14in

$v_i$ = 1056 in/s

$v_f$ = 0 in/s

m = 18 slugs

$v_{f^2} = v_{i^2} + 2a\ (x)$

$\Rightarrow 0^2 = (-1056\ in/s)^2 + 2(a)\ (14\ in)$

a= 39826.28in/$s^2$

$$v_f = v_i + at \tag{6}$$

$$0 = 1056 \text{ in/s} - 39826.28\text{in}/s^2(\text{t})$$

$$\text{t} = \frac{1056 \text{ in/s}}{39826.28\text{in}/s^2} = 0.02651\text{s}$$

*Impulse/momentum change:*

$$\text{F} = \frac{m * \Delta v}{t} \qquad\qquad (7)$$

Where:

m= 18 slugs

$\Delta v = 0 - 1056$ in/s = -1056 in/s

t= 0.02651s, the maximum force during impact is therefore, $\text{F} = \frac{-1056 \text{ in/s}}{0.02651\text{s}} = 39834.02$ lbf

## Center of Gravity

The center of gravity is a geometric property of any object; it is the average location of the weight of an object, and in this case the chassis design and its dead loads. The motion of a chassis can be described by the translation and rotation about its center of gravity. To determine the center of gravity, dead loads are taken into consideration, such as the space frame chassis design, the CBR 600 F4 engine, the seat, suspension system, shell, and a 95% percentile male [2]. Figure 9 shows the weight locations of the chassis, driver, suspension system and engine. Table 1 shows the weight of all the individual parts and where they are located from the reference point.

## Center of Gravity Formula

C. G= $\dfrac{W_1 L_1 + W_2 L_2 + W_3 L_3 + W_4 L_{4+} W_5 L_{5+} W_6 L_{6+} W_7 L_7}{W_{overall}}$ (8)

*C.G Analysis X-Axis*

$\dfrac{2271.00 lbft}{499.99 lbs}$ =4.542ft/54.505in

*C.G Analysis Y-Axis*

$\dfrac{1130.41 lbft}{499.99 lbs}$ =2.261ft/27.130in

*C.G Analysis Z-Axis*

$\dfrac{866.33 lbft}{499.99 lbs}$ =1.732ft

148
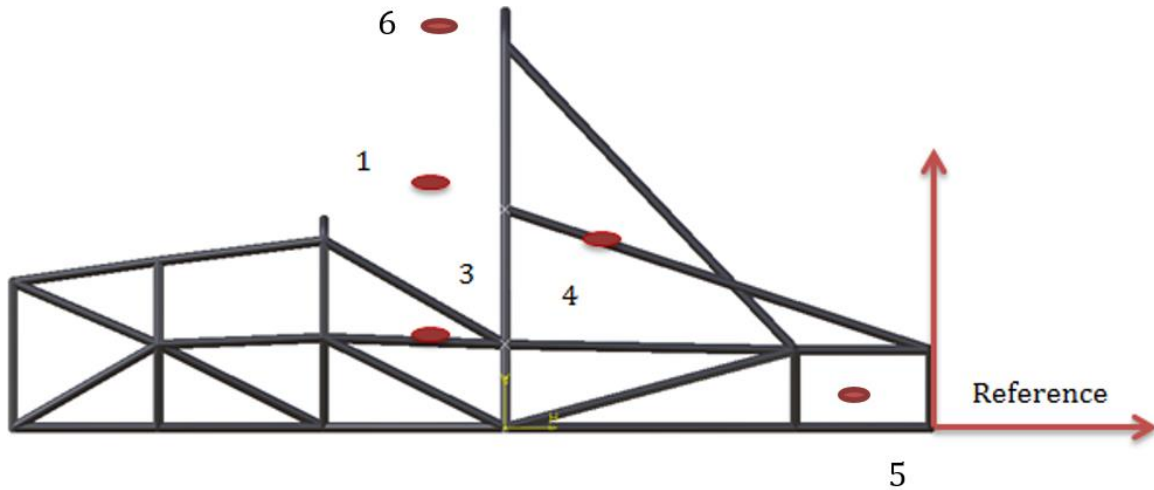
**Figure 9: Weight location with reference to the origin**

**Table 1: Center of Gravity Properties**

| No. | Items | Weight | X | WX | Y | WY | Z | WZ |
|---|---|---|---|---|---|---|---|---|
| 1 | 95% Percentile Male ………. | 225.00 lbs | 4.47ft | 1005.75lbft | 2.00ft | 450.00lbft | 1.744ft | 392.40lbft |
| 2 | Chassis……………………. | 48.90 lbs | 7.46ft | 364.79lbft | 4.63ft | 226.41lbft | 1.83ft | 89.487lbft |
| 3 | Seat…………………………. | 50.00 lbs | 4.47ft | 223.50lbft | 2.44ft | 122.00lbft | 1.76ft | 88.00lbft |
| 4 | Engine (CBR 600 F4) ……… | 126.00 lbs | 3.46ft | 435.96lbft | 2.00ft | 252.00lbft | 1.54ft | 194.04lbft |
| 5 | Suspension System one…….. | 20.00lbs | 6.96ft | 139.20lbft | 0.75ft | 15.00lbft | 0.50ft | 10.00lbft |
| 6 | Suspension System two……. | 20.00lbs | 0.50ft | 10.00lbft | 0.75ft | 15.00lbft | 2.00ft | 40.00lbft |
| 7 | Shell…………………….. | 10.00lbs | 9.18ft | 91.80lbft | 5.00ft | 50.00lbft | 5.24ft | 52.40lbft |
| Sum | Cumulative…………………. | 499.99lbs | | 2271.00lbft | | 1130.41lbft | | 866.33lbft |

**(ii) Finite Element Analysis (FEA)**

For the FEA analysis using CATIA, ordinary steel was used with a yield strength of $\sigma_{yp}$= 36.2ksi. After conducting a mesh convergence study, the most appropriate mesh size selected was 0.05 inches. Using the forces obtained from calculations for impact and inertia force around a corner, the stress on the chassis was determined. Figure 7 and 8 below shows the stress distribution on the chassis. The Side and Front impact analyses were conducted on the CATIA V5 software based on the following conditions; the front impact conditions were: velocity of 88ft/s; the side impact conditions were: velocity of 44ft/s. The color distribution specifies the stress along the chassis. The front impact stress suggests some high and medium stresses along the horizontal mid-trusses. The side impact stress suggests that there is a high stress concentration on the corners of the mid- trusses.

149
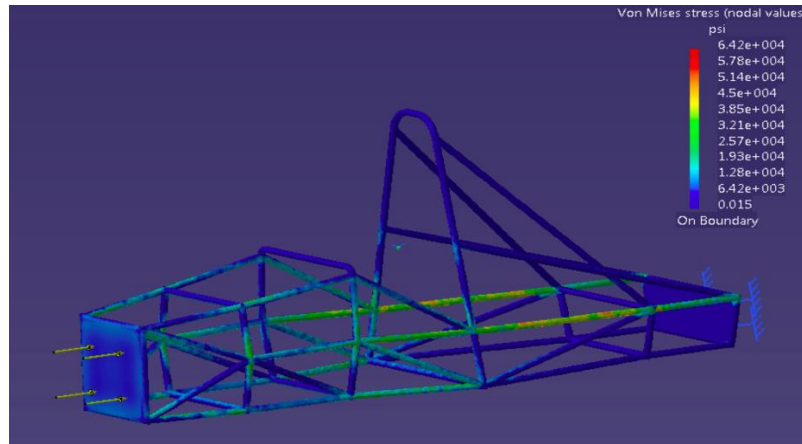
**Figure 7: Von Mises Stress for Front Impact**
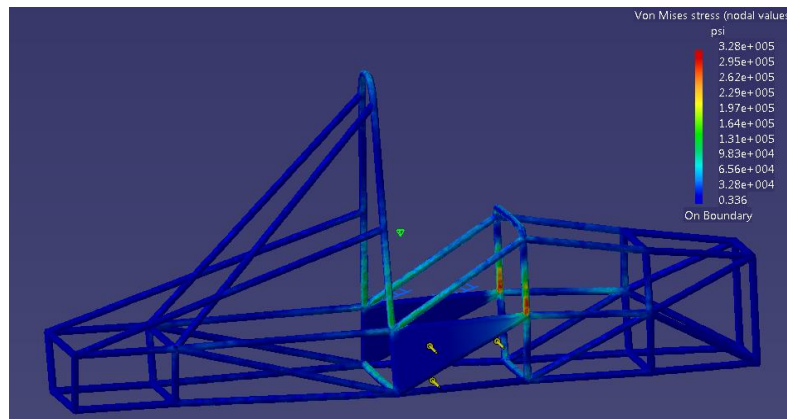


**Figure 8: Von Mises Stress for Side Impact**

Based on a factor of safety of 1.5, the allowable stress for a safe design of the chassis is 24ksi. Based on the analysis, few members would fail. In order to have a safe structure, these members were redesigned with a larger cross-section and other materials were considered, as observed in the material selection.

## 6. MATERIAL SELECTION

The chassis was tested using normal steel offered by CATIA. In order to determine the best material possible with which to build the chassis, a performance index test of different materials was conducted. Figure 10 shows the performance index and the corresponding types of materials. The FSAE rule book provides specific regulations on which materials to use when building a chassis. Only three materials were accepted: steel, aluminum, and engineering composites.  Aluminum is a lite-weight material but it is very expensive, difficult to weld together, and its usage requires special permission from the FSAE board.  Engineering composites can be used to create a monologue body. These save in weight, but they are expensive and infeasible for construction. Steel material became the main choice for the chassis. Table 2 shows four different types of steel that fell into the right category. The criterion needed

150

was a performance index of above 3, the region for steel alloy materials. Also the material required strength above 300 MPa (43.51ksi).

**Table 2: Material Properties**

| Material | Strength | Stiffness | Density | Performance Index | Cost per foot |
|---|---|---|---|---|---|
| 4130 Chromalloy | 97,200 psi | 63,100 psi | 0.284 lbs./in$^3$ | 5.5541 | $8.45 |
| 4130 Alloy Steel | 81,200 psi | 66,700 psi | 0.284 lbs./in$^3$ | 7.1338 | $8.81 |
| 1020 Steel | 57,249 psi | 42,748 psi | 0.284 lbs./in$^3$ | 3.7484 | $6.82 |
| 1010 Steel | 52,900 psi | 44,200 psi | 0.284 lbs./in$^3$ | 3.8754 | $6.82 |

For the different analysis conducted using CATIA FEA workbench, we closely studied each member, in order to determine how much force they will experience.
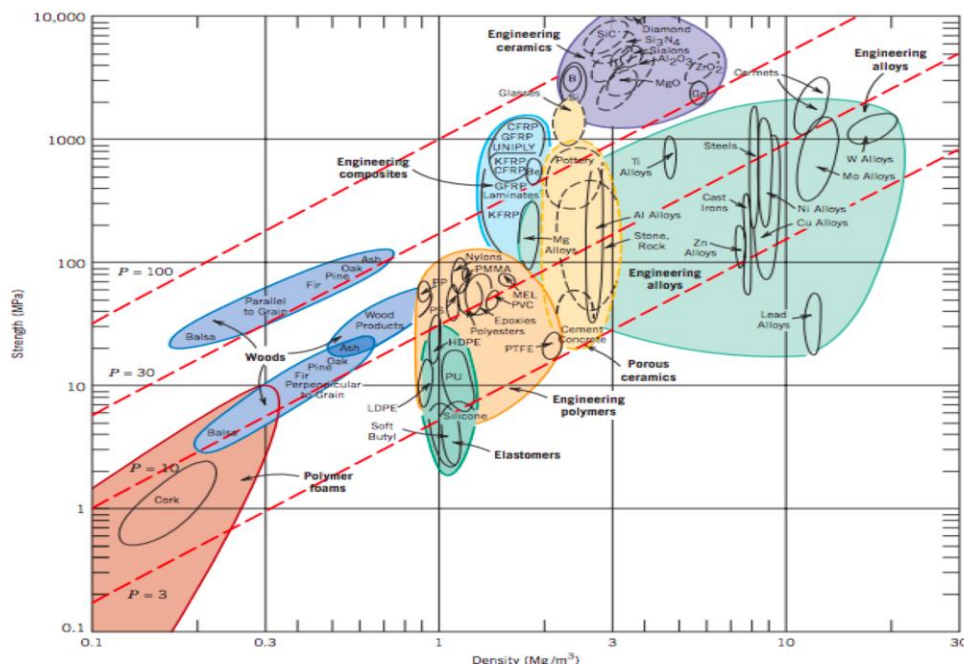


**Figure 10: Performance Index**

Using steel 1020 would provide an allowable stress of around 57 ksi, leading to complete failure for a total of five members.  Both 1020 and 1010 steel would not withstand collisions. 4130 Chromalloy is the strongest steel with the lowest cost.

Under the larger allowable stress of 97ksi, all members would be safe. Based on this determination, 4130 Chromalloy was selected for the chassis design. The performance index of the material is also above 5, and the price is comparable to other materials considered in the design process.

## 7. MANUFACTURING OF THE CHASSIS

To begin the manufacturing process, a total of 120 feet of 4130 Steel was ordered. Each section was cut in a manner to avoid waste [4]. The total waste was calculated to be 6.54 feet, not including leftover tubing, which totaled a length of 7.9 feet. This extra length will be recycled for mounting the engine and the seat, and possibly for the steering lever.

Since each individual piece was made-to-fit, some members needed to be re-cut and re-coved as needed. This created a smaller amount of waste, but larger parts were re-used in place of smaller members. After each member was measured and fitted, the member was clamped into place at the right angle and position, and was measured again to assure the highest accuracy. When the positioning was satisfactory, the joint was welded into place.



**Figure11: Coved sample 1**



**Figure12: Final Chassis**

In the engineering design for the chassis, the main hoop had a four inch radius and the front hoop had a two inch radius for two of the key bends, requiring custom molds for manufacturing. The closest bending mold to these dimensions was three-and-half inch, a size relatively easy to find in the industry. The radius change had minimal effect on the structural integrity. The front hoop is stronger than the engineering design, since the radius is bigger and the main hoop is weaker than the original design. However, the main hoop is supported by the crumble zone as well as structural reinforcement at two points with extra truss members, and therefore it will retain its structural integrity.

Once all the members were cut and bent some members were coved out for best welding contacts. Coving metal is the process of creating a small indentation or recess in a piece to compensate for the overlapping when it is joined to another piece. Figure 11 illustrates a coved piece.  Figure 12 shows the final manufactured chassis.

## 8.  CONCLUSION

The original goal of the project was to create a Vaughn College FSAE race club. In order to get the club up and running the team needed to design and build a chassis. The FSAE rule book of 2017 provided all of the necessary guidelines and restrictions. The first decision as a club was to decide if the team wanted to construct a space frame chassis or a monocoque body. Due to the time frame and resources available the decision was made to design a space frame chassis. All the critical sections of the body including the Main Hoop, Front Hoop, Side Impact Structure and Bulkhead were studied, leading to the sketch of an initial design which revealed the necessary modifications. The team then came up with a final design, which it studied using FEA analysis in CATIA. It was at this point modifications were made on the basis of determining where the chassis experiences the most stress. The next step is actually building the chassis. The father of one of our team members is an experienced welder who offered to help build the chassis. He has chosen to use a MIG, rather than TIG, welding technique.  This project is an effective means through which the team members obtain real world skills in research, development and manufacturing.

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[4] Welding Equipment ESAB North America | ESAB Welding & Cutting. (2000). Retrieved November 11, 2017, from http://www.esabna.com/

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# Team Cleaning Robots

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## ABSTRACT

This capstone research project, presents the development process of an innovative robotic vacuuming system. The system consists of two Omni-drive robots: a Slave Robot (SR) and a Master Robot (MR). The SR works independently. It sweeps dust and dirt from floor surfaces, including the corners of a room, beneath cabinets, and behind tables and other furniture. Additionally, it sends information/data to the MR. The MR computes an efficient path to vacuum dust and dirt in the sections of the room based on the information/mapping transmitted by the SR. Furthermore, the MR identifies garbage bin locations in an office by using Robot Operating System (ROS) and a Movidius Image Processing unit and empties these receptacles. Two autonomous robots in the vacuum system are programmed using ROS under Linux Ubuntu. A LIDAR is installed on each of the robots, and path-planning algorithms allow them to navigate around obstacles. The autonomous teaming robots are mainly designed to clean commercial office areas; however, they may also be used for residential spaces.

## 1. INTRODUCTION

One of the most unpleasant jobs in office or home maintenance is vacuuming. It is a duty that involves dragging around an unwieldy plastic hose connected to a clumsy wheeled canister for extended periods of time, depending on the room size. Robot vacuums are a new solution to this mundane task. These robot vacuums are equipped with lasers, sensors, and even Wi-Fi to autonomously navigate around the home. Unfortunately, due to their size, form factor, and lack of intelligence, these home cleaning robots cannot be utilized on an industrial level. Due to increases in the cost of cleaning companies, offices and industrial areas with larger spaces will benefit from an automatic cleaning system. Current automatic cleaning robots are still too clumsy and inefficient to be used in these settings.

The objective of this project is to develop a multi-robot system using the ROS framework to design and implement a completely autonomous and efficient cleaning system. The robots use

154

the various tools provided by the ROS framework, together with sensors, to collect and analyze data. The communication among the robots is used to map and clean an industrial or office environment more efficiently.

## 2. BACKGROUND RESEARCH

A robot vacuum cleaner is an autonomous vacuum system that can make intelligent decisions based on sensor inputs. The first robot cleaner that appeared on the market was Electrolux Trilobite [1], a vacuum system developed by James Dizon and purchased by the appliance manufacturer Electrolux. In 2001, the British technology company Dyson built a vacuuming robot known as DC06 [2]. However, due to the high cost, it was never released on the market. In 2002, the American advanced technology company iRobot launched the Roomba floor-vacuuming robot [3]. Due to its small and compact design and the novelty of owning an automated vacuum, the Roomba was a large consumer success. Ever since, there have been several variations of robotic vacuum cleaners on the market. As of 2017, 23% of vacuum cleaners sold are robots [4]. Nevertheless, all of these robots have a similar weakness, which is the lack of an efficient path planning program, as shown in Figure 1. They use various sensors, such as sonars and ultrasounds to detect and avoid obstacles. But these types of sensors are unable to map the area to be cleaned. As a result, over the course of operations, a robot can repeatedly vacuum the same 25% of an area while leaving 20% of it uncleaned [5]. To enhance automated vacuum efficiency and to save time and energy, a modern robot vacuum system with mapping and path-planning algorithms was developed. One problem with a massive robot cleaner is its inability to vacuum the dirt and dust in small or tight corners, due to its large size. However, if the robot is small in size, it may not be powerful enough to clean a large office area or workshop. Team robots developed in this project will solve these problems. Further, the MR designed here is capable of emptying bin disposal units in an office area, making the current robot vacuum system an appropriate choice for office workspaces.



**Figure 1**: Long-exposure photo showing the paths taken by a Roomba over 45 minutes

## 3. ENGINEERING REQUIREMENTS AND DESIGN CONSTRAINTS

➢ Specifications for the working environment of the team robot system

- Cleaning area:           20m×10m
- Time for cleaning:       120 minutes

155

- ➢ Specifications for Master Robot:
  - Size                          $620 \times 360 \times 295$ mm$^3$
  - Maximum payload:              2 kg
  - Body weight:                  28 kg
  - Maximum speed:                0.22 m/s
  - Ground clearance:             1 cm
  - Continuous operation:         120 minutes
  - Drive hardware configuration: Differential wheeled with 2 drive wheels and 4 casters
  - Drive software requirement:   Autonomous navigation and obstacle avoidance
  - Battery requirement:          (x2), 22Ah sealed lead-acid batteries

- ➢ Specifications for Slave Robot:
  - Size                          $250 \times 150 \times 50$ mm$^3$
  - Body weight:                  1.8 kg
  - Maximum speed:                0.35 m/s
  - Ground clearance:             1.5 cm
  - Continuous operation:         120 minutes
  - Drive hardware configuration: One motor drives two back wheels and one turning wheel
  - Drive software requirement:   Autonomous navigation and obstacle avoidance
  - Battery requirement:          (x1), Zippy 6000 mAh 30C Li-PO Battery

- ➢ Specifications for motors:
  - Master Robot
    Maixmum torque:               $\geq$65 kg-cm

  - Slave Robot
    Maixmum torque:               $\geq$1.65 kg-cm

- ➢ Specifications for sensors:
  - Angular range:               360 degree
  - Detection distance:          0.12m ~ 3.5m
  - Accuracy:                    1.5cm ~ 17.5cm

- ➢ Safety requirements:
  An emergency stop is incorporated in each robot. In the event of an emergency, when either emergency stop button is pressed, both robots will automatically stop. The exhaust port is well covered with mesh in order to protect from accidental contact with the vacuum blades.

- ➢ Health requirements:
  A filter installed on top of the exhaust port keeps particles, cleaned from the floor, inside the vacuum receptacle.

156

> Summary of Requirements:
> This project included the development of two autonomous commercial office-cleaning robots. The SR sweeps dust and dirt. It creates a two-dimensional map of its environment using its light and range detection (LIDAR) sensor. The MR uses the map transmitted by the SR for its path-planning algorithm and determines the best path for the slave robot and the MR to efficiently clean the room. Additionally, the MR vacuums dust and dirt swept by the SR. Further, it identifies trash bins placed around the office by using ROS and a Movidius Image Processing unit, and it empties these bins and returns them back to their proper location.

**Table 1:** Engineering Parts and Specifications

| Items | Master Robot | Slave Robot |
|---|---|---|
| Maximum Translational Velocity | 0.22m/s | 0.35m/s |
| Maximum Rotational Velocity | 1.82rad/s | 2.84rad/s |
| Maximum Payload | 2kgs | N/A |
| Size (L x B x H) | 281mm x 306mm x 141mm | 42mm x 29mm x 18mm |
| Weight (+ SBC + Battery + Sensors) | 28kg | 1.8kg |
| Operating Time | About 2hr | About 2hr |
| Motor | Robotis dynamixel | Robotis dynamixel |
| Single Board Computer (SBC) | Raspberry Pi 3 | Raspberry Pi 3 |
| Embedded Controller | OpenCR (32bit ARM® Cortex®-M7) | N/A |
| Image Processing | Intel® Movidius Compute Stick | N/A |
| Sensors | HLS-LFCD2 Lidar | HLS-LFCD2 Lidar |
| | 3-axis accelerometer | 3-axis accelerometer |
| | 3-axis gyroscope | 3-axis gyroscope |
| | 3-axis magnetometer | 3-axis magnetometer |
| | Raspberry Pi Camera | |

## 4. ROBOT CLEANING SYSTEM DESIGN

Because it is necessary to develop the behavior of the robots, it is also necessary to optimize their shape, sensor and actuator system. All of these criteria (shape, sensors, motors, software) must not only be designed individually, but also as a whole. Only with a total integration of hardware and software is such an application be feasible.

## 4.1. ROBOT BODY DESIGN
### 4.1.1. MOTOR SELECTIONS

The MR has a differential drive configuration. Based on the preceding specification, the motor torque values can be determined first. From the payload value and robot body weight, the motor torque can be computed. The number of wheels is six, including four caster wheels and two wheels undergoing actuation. Assuming that the coefficient of friction is 0.6, wheel radius is 5

157

cm. The following formulas can be used to calculate the maximum torque applied to the MR for movement:

- Total Weight of the Robot

$$W_T = W_R + P, \tag{1}$$

where,
    $W_T$ = the total weight of the robot
    $W_R$ = mass of robot $\times$ gravity (mg = 28 [kg] x 9.8 [m/s$^2$] $\approx$ 275 N)
    P   = payload (2 [kg] x 9.8[m/s$^2$] $\approx$ 20N)

From Eq. (1), $W_T$ can be solved as follows:

$$W_T = W_R + P = 275 \text{ [N]} + 20[N] = 295 \text{ [N]} \tag{2}$$

- Maximum Torque Equation 'T'

If the robot is stationary, the motors attached to the wheels must exert a maximum torque in order to move. The maximum torque equation can be written as follows:

$$\mu \times N \times r - T = 0 \tag{3}$$

where,
    $\mu$ = Coefficient of friction with value of 0.6
    N = Average weight acting on each wheel (Total weight of robot / 2 [N])
    r = Radius of the wheels (5 cm = 0.05 [m])
    T = Maximum torque to get moving [N.m]

Since the weight of the robot is equally distributed among all six wheels, but only two are actuated, the average weight of the MR can be considered as the total weight of the robot divided by two. Then, the average weight acting on each wheel can be calculated as follows:

$$N = W_T / 2$$
$$= 295 \text{ [N]} / 2 = 147.5 \text{ [N]} \tag{4}$$

From Eq. (3), the maximum torque can be solved by:
$$T = \mu \times N \times r = 0.6 \text{ x } (295/2) \text{ x } 0.05$$
$$= 4.425 \text{ N-m}$$
$$= 45.15 \text{ kg-cm} \tag{5}$$

To ensure the motors are able to provide enough torque, a motor with the torque larger than 65 kg-cm for the wheels was chosen. Similarly, for the SR, a wheel radius of 3cm is used. Thus, the required maximum torque for the smaller robot was calculated and found to be 0.162N-m or 1.65 kg-cm.

### 4.1.2. SENSOR SELECTION

According to the requirements, the power available for team cleaning robots should last 120 minutes within a cleaning area of 10$\times$20 m$^2$. The accuracy of the sensor measurement  must be less than 17.5cm to guarantee an acceptable navigation. Based on these requirements, the LIDAR sensor was selected to detect obstacles and provide mapping information of the cleaning area for the path planning algorithms. Lidar sensors, in particular, provide advantages for obstacle

boundary detection, including a higher resolution over a wider field than other more commonly used sensors.

## 4.2. MASTER ROBOT FRAME DESIGN

First, in order to select the best frame for the application, we reviewed existing robots on the market. The existing robots round shape is a disadvantage in the cleaning of corners. Furthermore, a complex trajectory is required to clean around small obstacles, such as furniture legs, which causes the existing robots to freeze at the obstacle point. Creating a D-shape robot is a convenient option for this study.
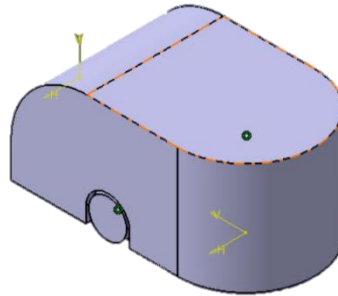


**Figure 2:** Isometric View of Master Robot

Figure 2 is the view of the MR as seen from the back left side. The curved surface serves a dual purpose. It is safer for the user and creates a large access point to the robots internal collection bin, compared to a single flat door. This access allows for easier vacuum container dumping and facilitates any maintenance that may be necessary. On either side of the robot, there is one wheel which propels it. The centered location of the wheel allows for easy control and navigation, so turns can be made on a central axis. The single wheel is also the support point for the highest concentration of the robot's mass.
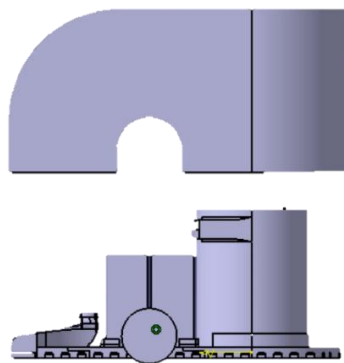


**Figure 3:** Side View Casing Removed of Master Robot

Figure 3 shows the side view of the MR with the outer casing lifted, revealing the internal components. The object labeled (a) is the vacuum head. The two center columns labeled (b) are the batteries. The batteries are the heaviest components, and as such, require the most structural support. The object labeled (c) is the wheel, which provides the support for the batteries and drives the robot. The object labeled (d) is the vacuum container, which houses the fan and dirt receptacle.

159
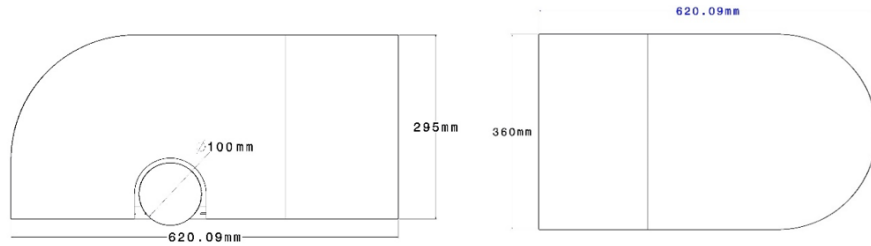
**Figure 4:** Isometric Casing Removed View of Master Robot

Figure 4 shows the side and top views of the MR with major axis dimensioning. The MR is 295mm tall, which is large enough to hold a large amount of debris, but still small enough to fit under most office chairs and desks. The width of the MR is 360mm, which allows for a wide coverage area of the vacuum head and brush.
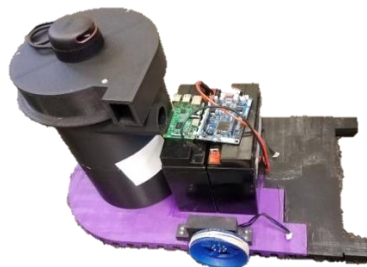


**Figure 5:** Master Robot Assembled Without Casing

Figure 5 shows the MS assembled with the casing removed. The motor can be seen mounted to the base with a wheel attached. The two batteries, Raspberry Pi board and the motor controller stand at the center of the base. The LIDAR is on top of the vacuum section to avoid obstruction.

### 4.3. SLAVE ROBOT FRAME DESIGN
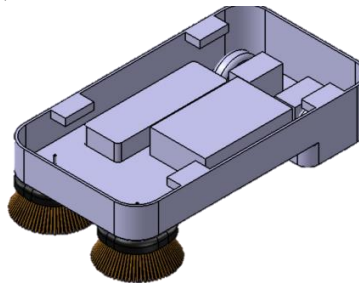


**Figure 6**: Isometric View of Slave Robot Design

Figure 6 is the view of the SR from the back left side. Two wheels, each with an individual motor, drive the SR. Two circular brushes protrude from the bottom of the base and make contact with the floor. These brushes rotate and sweep dust and dirt from hard to reach places, such as baseboards and corners. The shell protects the internal components and leaves space for easy access to the battery container.



**Figure 7:** Side View of Slave Robot

160

Figure 7 is the side view of the SR. Both the wheel and brush can clearly be seen. The tip of the brush is slightly lower than the bottom of the wheel, a feature that applies pressure on the brush, making a better sweep with more brush to floor surface contact.



**Figure 8:** Slave Robot Assembled

Figure 8 shows the SR assembled with the two motors mounted at the rear of the robot and the battery, Raspberry Pi board, and motor controller at the center. The front compartment is open to allow the brushes to be recessed with their motors in order to keep dust particles away from any electronic components.

### 4.4. ROBOT EQUIPMENT
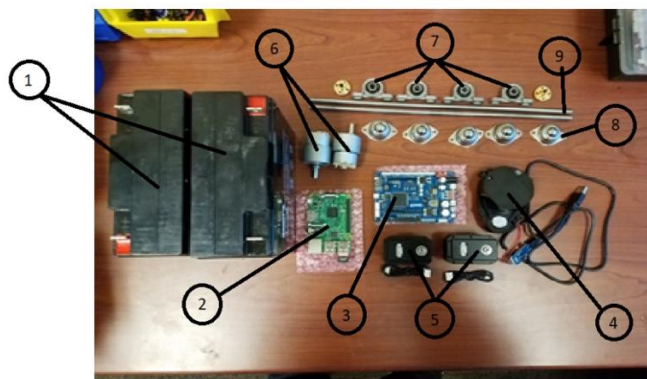


**Figure 9:** Equipment for Master Robot

Figure 9 shows the various hardware and electronic components of the MR. Each component is labeled and can be seen in Table 2. The components of the small robot are similar using much of the same electronic components, specifically the Raspberry Pi 3 (2), Embedded controller (3), LIDAR (4), and Dynamixel Motors (5), along with a continuous FS90R servo motor.

**Table 2: Master Robot Equipment Identification**

| | |
|---|---|
| 1 | Lead Acid Battery |
| 2 | Raspberry Pi |
| 3 | Embedded Controller |
| 4 | LIDAR |
| 5 | Dynamixel Motors |
| 6 | 12V DC motors |
| 7 | Ball Bearings |
| 8 | Ball casters |
| 9 | Threaded rods |

**4.5. ROS SYSTEM, SIMULATION AND SOFTWARE FLOWCHART**

The cleaning robots are programmed using ROS, an open source framework that allows the development of multiple components of a robotics system with the goal of sharing and porting them to other robots with minimal changes. It is an operating system that provides regular service a user would expect, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. The ROS environment also provides tools and libraries for obtaining, building, writing, and running code across multiple computers [6]. Programs in ROS utilize processes called Nodes to perform computation. These processes communicate with one another by publishing and subscribing to messages via named buses known as Topics. These nodes are developed to operate on a minuscule scale; a robot control system will usually comprise many nodes. For example, one node controls the on/off switch of a laser range finder, another controls the robot's wheel motors, the third one performs localization, the fourth node performs path planning, and so on [7]. One major benefit of multiple nodes is an increase in fault tolerance as crashes in a system are isolated to individual nodes in the program.
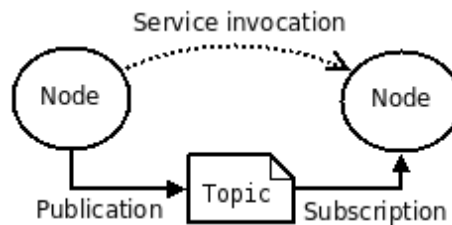


**Figure 10**: Node Communication

As a part of the robot design, the programs and algorithms are simulated using a tool in ROS called Gazebo. Gazebo is a multi-robot simulator for complex indoor and outdoor environments. It is capable of simulating a population of robots, sensors, and objects in a three-dimensional world. It generates both realistic sensor feedback and physically plausible interactions between objects [8]. In the Gazebo simulator, the user will design an environment and spawn robot models into this environment. The developed algorithms can be tested and improved based on the results obtained from the simulation. To speed up the experimental process, two TurtleBot3 robot models, *burger* and *waffle,* were used for performance verification and validation. The TurtleBot3 models have open-sourced robot description files that can be modified for specific needs [9].
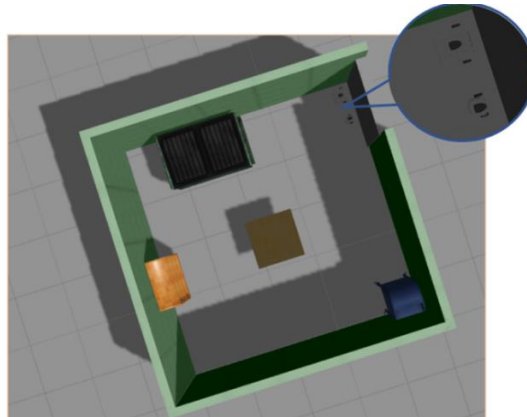


**Figure 11**: Gazebo Simulated World with Master and Slave Robots

```
18
19    #include "turtlebot3_gazebo/gazebo_ros_turtlebot3.h"
20
21    GazeboRosTurtleBot3::GazeboRosTurtleBot3()
22      : nh_priv_("~")
23    {
24      //Init gazebo ros turtlebot3 node
25      ROS_INFO("TurtleBot3 Simulation Node Init");
26      ROS_ASSERT(init());
27    }
28
29    GazeboRosTurtleBot3::~GazeboRosTurtleBot3()
30    {
31      updatecommandVelocity(0.0, 0.0);
32      ros::shutdown();
33    }
34
35    /*******************************************************************************
36    * Init function
37    *******************************************************************************/
38    bool GazeboRosTurtleBot3::init()
39    {
40      // initialize ROS parameter
41      nh_.param("is_debug", is_debug_, is_debug_);
42      std::string robot_model = nh_.param<std::string>("tb3_model", "");
43
44      if (!robot_model.compare("burger"))
45      {
46        turning_radius_  = 0.08;
47        rotate_angle_  = 50.0 * DEG2RAD;
48        front_distance_limit_ = 0.7;
49        side_distance_limit_  = 0.4;
50      }
51      else if (!robot_model.compare("waffle"))
52      {
53        turning_radius_  = 0.1435;
54        rotate_angle_  = 40.0 * DEG2RAD;
55        front_distance_limit_ = 0.7;
56        side_distance_limit_  = 0.6;
57      }
58      ROS_INFO("robot_model : %s", robot_model.c_str());
59      ROS_INFO("turning_radius_ : %lf", turning_radius_);
60      ROS_INFO("front_distance_limit_ = %lf", front_distance_limit_);
61      ROS_INFO("side_distance_limit_ = %lf", side_distance_limit_);
```

**Figure 12:** Gazebo Class Program

```
/*******************************************************************************
* Control Loop function
*******************************************************************************/
bool GazeboRosTurtleBot3::controlLoop()
{
  static uint8_t turtlebot3_state_num = 0;
  double wheel_radius = 0.033;
  double turtlebot3_rotation = 0.0;

  turtlebot3_rotation = (rotate_angle_ * turning_radius_ / wheel_radius);

  switch(turtlebot3_state_num)
  {
    case GET_TB3_DIRECTION:
      if (direction_vector_[CENTER] > front_distance_limit_)
      {
        turtlebot3_state_num = TB3_DRIVE_FORWARD;
      }

      if (direction_vector_[CENTER] < front_distance_limit_ || direction_vector_[LEFT] < side_distance_limit_)
      {
        priv_right_joint_encoder_ = right_joint_encoder_ - turtlebot3_rotation;
        turtlebot3_state_num = TB3_RIGHT_TURN;
      }
      else if (direction_vector_[RIGHT] < side_distance_limit_)
      {
        priv_right_joint_encoder_ = right_joint_encoder_ + turtlebot3_rotation;
        turtlebot3_state_num = TB3_LEFT_TURN;
      }
      break;
```

**Figure 13:** Control Loop for Robots in Gazebo
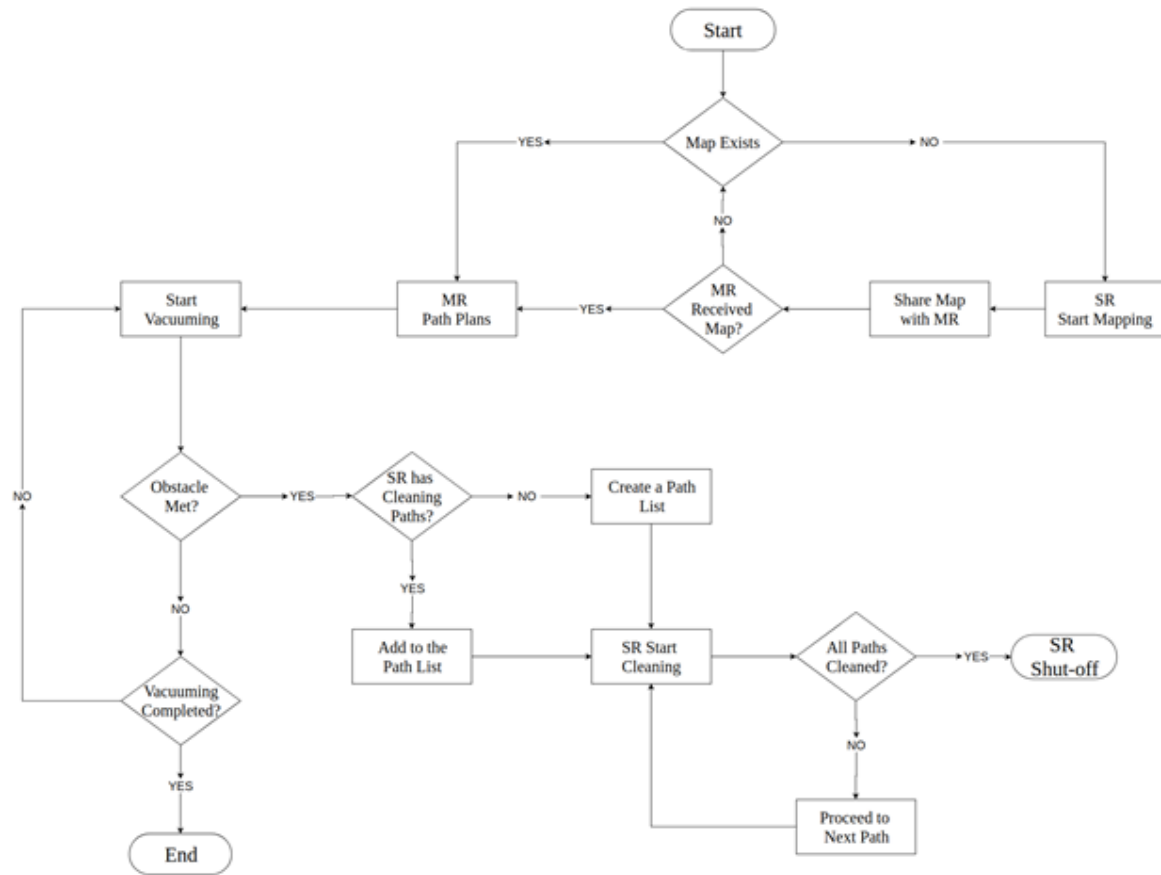
**Figure 14:** Simulation Algorithm Flowchart

Figure 14 shows the program flowchart for simulation. At the start of the program, a memory check determines whether there is any existing map of the location. If a map already exists, the MR proceeds to path plan its navigation around the room to clean it efficiently. If there is none, the SR starts mapping the area, and upon completion, shares the map with the MR. If the map is shared successfully, the MR starts the path planning and the SR enters standby mode. On the other hand, if the MR does not receive the map, the SR repeats the process of mapping the area. Once the path planning is complete, the MR proceeds to navigate and vacuum the mapped area. If an obstacle is met on the way and it is deemed cleanable by the SR, the MR directs the SR to clean the area. The SR exits standby mode to perform its designated function of cleaning a specified area. Once done, the SR resumes its standby mode and awaits further instruction from the MR. The MR repeats this process until it is finished navigating the mapped area, thus ending the vacuuming process, which in turn ends the whole program.

## 4.6. ROBOT CONTROL AND NAVIGATION

The two robotic vacuum cleaners are controlled using two embedded microcontrollers, OpenCR and OpenCM. The OpenCR is an open-source control module for ROS, with a STM32F7 chip based on the ARM Cortex-M7 while the OpenCM is based on the ARM Cortex-M3. Both controllers are used to control the sensors and actuators on the robots. To communicate between the embedded controllers and the Single Board Controllers(SBCs), we utilized the rosserial package. This is a package that converts ROS messages, topics and services from the SBC to a serial communication to the embedded controllers. To navigate, data from the LIDARs and Inertial Measurement Units (IMU) are sent to the SBC to determine the robot's pose on the map. The robot's location is then compared to the target location and the SBC performs the SL

164

operations to determine the motion required to get the robot to the target. These motion parameters are sent to the dynamixel motors with built in encoders to precisely rotate the wheels. Feedbacks from the wheels encoders are used by the SBC to ensure the robot has reached its target.

## 5. CONCLUSION

Robotic vacuum cleaners are gaining popularity among consumers who desire to save time during weekly vacuuming. Many existing robots have designs that implement spinning brushes to reach tight corners, while others incorporate cleaning features such as mopping, waxing, UV (Ultra Violet) sterilization, etc. However, these robots do not effectively map and plan their vacuum operation paths. Using tools and frameworks in ROS, the objective of this project was to design a cost-effective and user-friendly robot vacuuming system to increase the efficiency and capabilities of the current systems. The development of this system will encourage the creation of similar systems that may be integrated into the home Internet of Things (IoT).

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# GSM Based Smart Hub

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## ABSTRACT

Modern security systems offer peace of mind by providing an extra set of senses while a house or building is unoccupied. These systems utilize simple sensors, continuously monitor motion, temperature and smoke in real-time, and relay the raw data to a central hub or a processor. The main hub collects data from the peripheral sensors and processes that data into information that is used to determine if the owner or authorities should be alerted or an alarm should be sounded or both. If any abnormalities are detected, the system will respond by alerting the user. The alert can be audible as well as a text message. This project explores a new way for home security systems to communicate with users in the event of an emergency. This project demonstrates a cost-effective, commercial-off-the-shelf (COTS) smart home system using a central microcontroller and peripheral sensors.

## 1. INTRODUCTION

Technological advances in home security systems are approaching a standstill. Mainstream systems operate on a switch mechanism. For example, if an intruder breaks the lock on a door and the door is opened, an alarm will sound and the main security hub will call the local authorities. The problem with this system is that burglars can find other means of entering a house such as breaking a window. Also, they can cut the power from the house so the alarm would not be functional. A possible solution is to add cameras and more sensors around the house to extend coverage, but this can be costly.

A simple solution is to make the alarm system completely wireless and smarter by utilizing simple sensors, a powerful microprocessor and GSM communication. This system encompasses different sensors to aid in the discovery of different types of emergencies such as intrusion and fire. In short, if a sensor detects motion or a fire, the user will get a text message regardless of his or her location.

GSM communication does not rely on a proprietary network. Instead, it connects to multiple networks to ensure delivery of the alert to the user and the authorities. The hub houses the sensors within itself, which saves time and effort when installing. Inexpensive sensors reduce costs and work efficiently with hardly any issues. An added benefit of using this system is that many more sensors can be added in different locations.

166

## 2. CONCEPTUAL SKETCH

Any electronic device that can connect to a network and provide useful information is considered a "smart device". Various appliances such as refrigerators, thermostats, and lights all have some type of Internet connectivity that allows for user interaction. The smart devices also work together to keep the home secure when it is unoccupied. Alarm systems can warn the home owner of any discrepancies such as fire, intrusion, flood, and gas leaks [1]. Over time, the devices learn the usage pattern of occupants around the house. For example, a smart thermostat will log information about when the house is empty, so it can automatically turn off the heat, which will reduce the energy bill. These appliances are part of a growing network called the Internet of Things (IoT) [2].



**Fig-1: Smart Home Concept [1]**

## 3. SYSTEM BLOCK DIAGRAM DISCUSSION

The model used to demonstrate this project consists of a central microcontroller that samples data from a flame sensor, motion detector and a temperature sensor, performs comparisons based on program algorithm running on the microcontroller, and outputs an alert to the user on their cell phone over a GPRS wireless network.

167
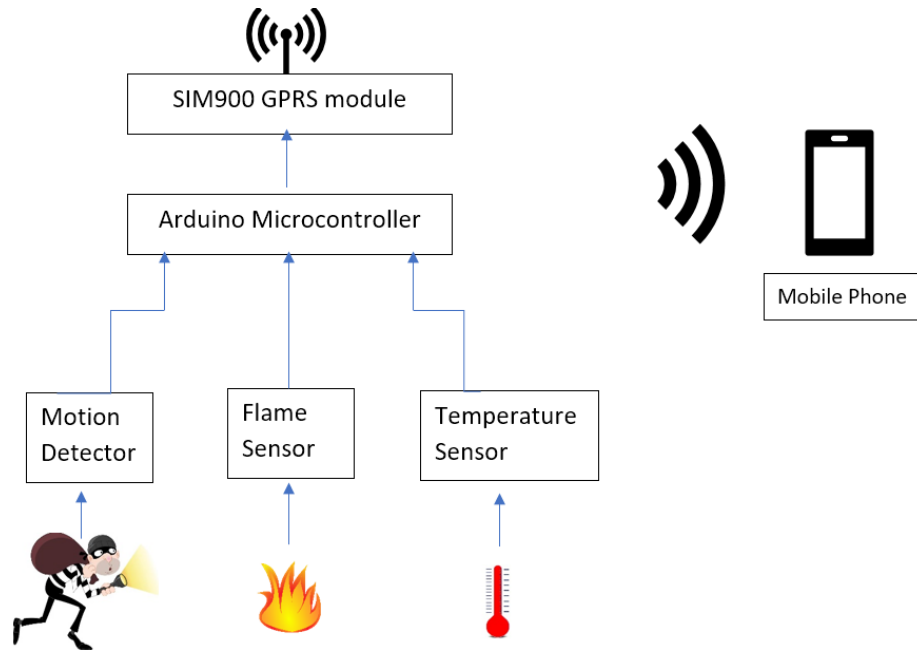
**Fig-2: System Block Diagram**

### 4. TECHNICAL DESIGN

When the system is powered on, the sensors begin the initialization process by running their calibrations. Meanwhile, the GPRS module establishes a connection with the mobile network provided by the carrier of the SIM card. Once all sensors and modules are running, the Arduino microcontroller executes the code that will continuously loop.

The LM35 temperature sensor and the flame sensor module use analog pins with defined thresholds. The motion sensor uses a digital pin which utilizes the HIGH or LOW function. The block diagram (Fig-2) demonstrates how this device operates. When a person enters the range of detection for the motion sensor, it returns a HIGH value to the microcontroller. The microcontroller reads the HIGH value and executes the command for the SIM900 module to send the predefined text message. After the execution, a delay is introduced to prevent multiple messages from being sent in a short period of time.

The flame and temperature sensors operate in a similar fashion, with one exception. Since these sensors are running on analog ports, a set value must be defined in the code so that the microcontroller can detect a trigger and perform the necessary actions. The LM35 produces raw values ranging from 0 to 1023 [3]. Each integer is converted to degrees Celsius by using a formula. There are low and high temperature thresholds defined in the code. When the condition is met, the microcontroller will run the command for the SIM900 GPRS module to send the corresponding text message. As previously mentioned, the flame sensor follows the square law.

For the sensor to pick up a flame that is twice the distance away, the flame would have to be four times as large. The analog values range from 0 to 1023. If a flame is detected within the field of view of the sensor, the analog value will decrease with respect to range.

168

The decision was made to use compatible Arduino shields to eliminate issues with compatibility. The overall system is compact because the shields stack on top of each other. They use power from the main Arduino board, eliminating wire clutter. The I/O pins from the main Arduino board "carryover" to the other shields so they can be easily accessed. A main criterion of this project is to make the device so that it appears unobtrusive. The benefit of using GSM networks for communicating with the user is that cell networks rarely go down. If one cell tower is inoperable, the SIM900 module will connect to another tower to pass the message to the end user. This system is designed so that many other sensors can be added to provide full home coverage.

### 4.1. TEMPERATURE SENSOR

One of three sensors that are present in this smart hub device is a simple LM35 temperature sensor. The LM35 is a precision integrated circuit analog sensor with a linear output voltage that is proportional to the Centigrade temperature (+10-mV/°C). This sensor does not require any calibration to provide accurate readings. The LM35 is rated between -55°C to 150°C. This sensor operates from 4V to 30V with less than a 60μA current drain. This temperature sensor was chosen due to its small size (4.3mm) and low cost of $1. Its main function is to detect abnormalities in the room temperature [3].
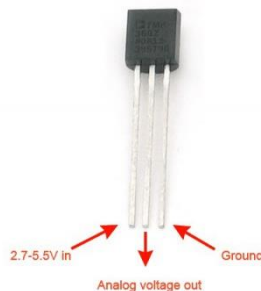


**Figure-3: LM35 Temperature Sensor [3]**

For detecting motion, a Passive Infrared Sensor (PIR) module is used. This sensor operates between 5V to 20V and consumes 65mA of current. Its sensing range is 120 degrees within 7 meters. The PIR sensor encompasses two slots that are sensitive to IR. When the sensor is idling, both slots detect the same amount of IR that is radiated from the walls inside the room. When a warm body passes by, a positive difference is detected and the sensor outputs logic 1. When the warm body leaves the area, the sensor returns to logic zero. In most cases, a Fresnel lens covers the IR sensor. Each facet contains different Fresnel lenses which allows for a broader detection range [4].



**Figure-4: PIR Motion Sensor [4]**

169
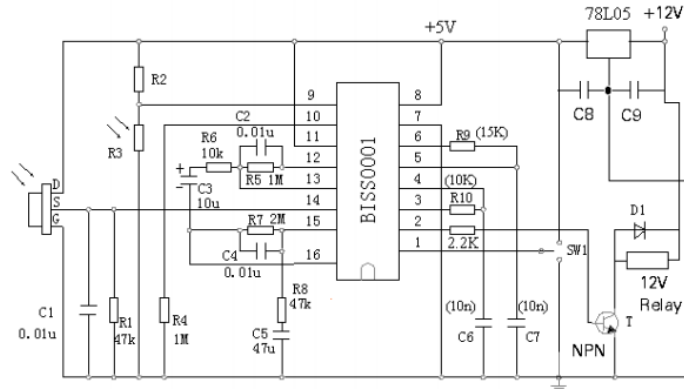
**Figure 5: Circuit Schematic for BISS0001 IR Sensor Processor [5]**

### 4.2. TEMPERATURE SENSOR

The flame sensor module is used to detect the radiation wavelength emitted from a flame. This wavelength is in the range of 760nm to 1100nm. The module comprises of an IR sensor, LED indicator, and a potentiometer. This module operates between 3.3V to 5V and produces both analog and digital outputs. The detection threshold can be adjusted by use of the potentiometer. The detection range relies upon the square law. This means that for the motion detector to register an IR signature from double the distance, the size of the flame would have to be four times greater [6].



**Figure 6: KY-026 Flame Sensor with LM393 OpAmp [6]**
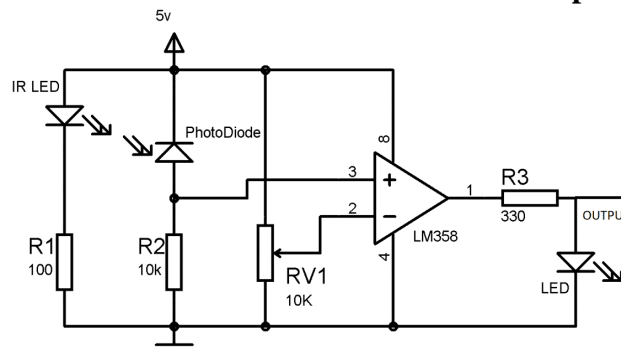


**Figure 6: Flame Sensor Circuit Schematic using LM358 and IR LED [7]**

### 4.3. GPRS ARDUINO SHIELD

The GPRS[1] (General Packet Radio Service) module is a shield that stacks on top of the Arduino microcontroller. This shield is responsible for sending the text messages to the mobile phone.

---

[1] General Packet Radio Service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM).

170

The heart of this shield is the SIM900 module. This module operates on GSM (Global System for Mobile communication) networks in all countries around the world. Specifically, it operates on the 850/900/1800/1900 MHz bands. The SIM900 also supports AT (ATtention) commands. AT commands are instructions used to control a modem, such as dial (ATD), answer (ATH), send SMS message (AT+CMGS), and read SMS (text message) (AT+CMGR). The GPRS shield will accept any unlocked SIM card for communication. The SIM card must be registered on a GSM network. The shield also features headphone and microphone jacks for making calls, a power selection switch, antenna interface, and a status LED. However, only the SMS function is utilized for this project, which draws less than 500mA [8].
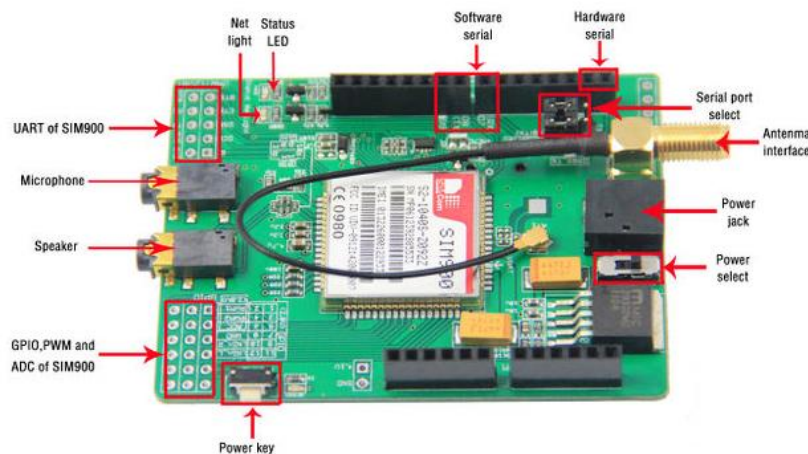


**Figure 6: SIM900 GPRS Shield [8]**
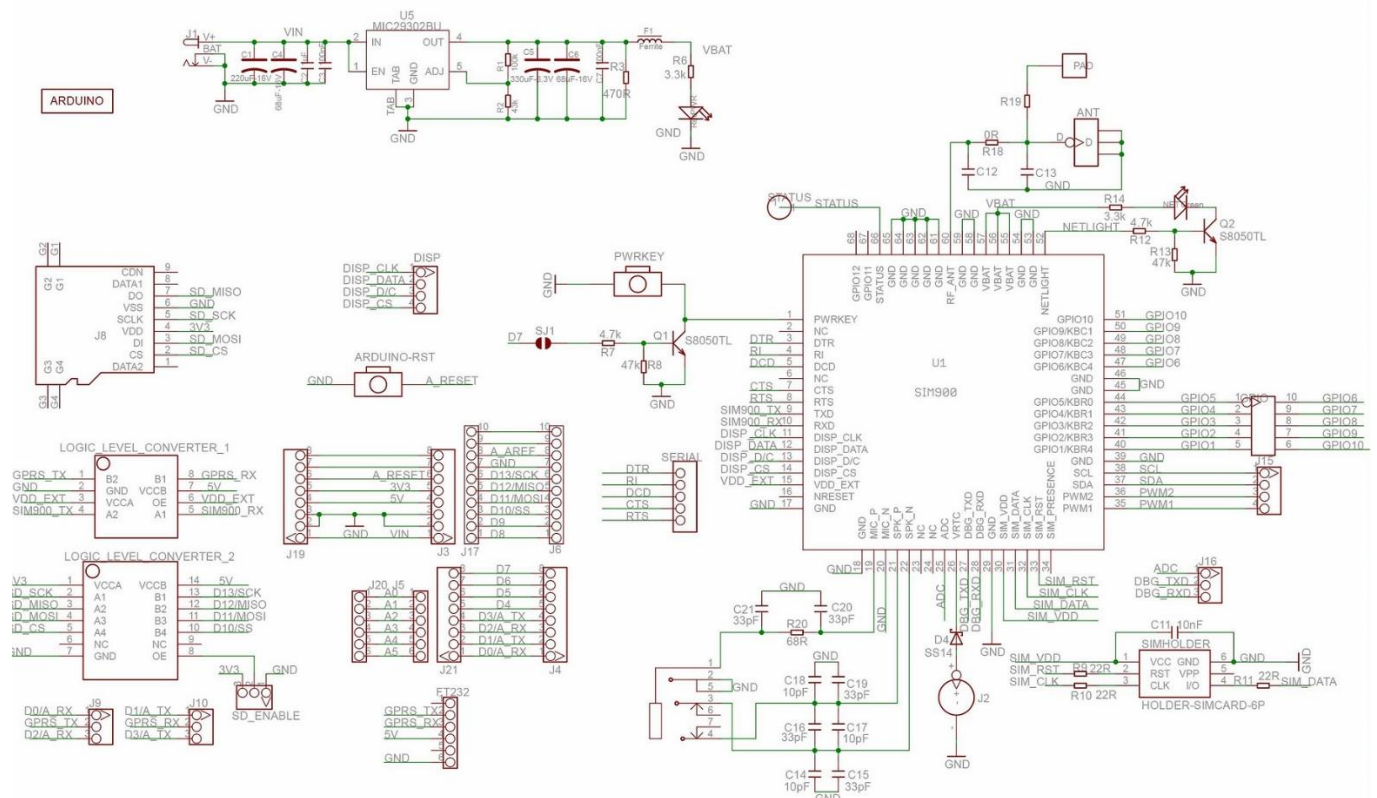


**Figure 7: Schematic - ATMega328P Interface with SIM900 GPRS [9]**

171

### 4.4. SEEEDSTUDIO BASE SHIELD V2

The Seeedstudio Base Shield V2 presents an alternative for connecting the sensors to the Arduino microcontroller. This shield has individual ports which include the exact number of pins as the Arduino board. By using the compatible cables, the sensors are easily attached on to their respective I/O ports. Each port supplies 5VDC, ground, and a digital/analog pin. If sensors use 3.3V, there is a switch for that option. This shield eliminates the need for a traditional breadboard for connecting the sensors to the microcontroller.
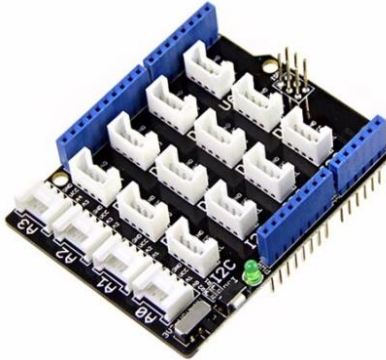


**Figure 6: Seeedstudio Base Shield V2 [10]**

### 4.5. ARDUINO MICROCONTROLLER

For this project, the Arduino Microcontroller is an ideal choice that utilizes a small footprint in terms of size and power consumption. The heart of this board is the ATmega328p microcontroller. The ATmega328p has 32KB of flash memory, 2KB of SRAM, 1KB of EEPROM and a clock speed of 16MHz. This microcontroller board can accept traditional USB power (5V), as well as power from an external adapter (7-12V). There are a total of 20 I/O pins, 14 of which are digital and 6 of which are analog. In addition to the specifications mentioned above, the Arduino microcontroller has small size of 68.6mm by 53.4mm which makes it an ideal choice for constructing this project [11].
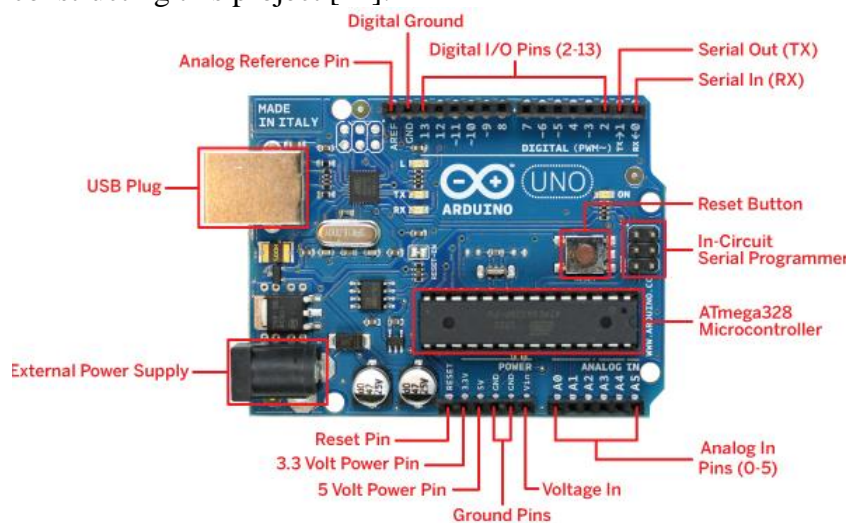


**Figure 5: Arduino Microcontroller [11]**
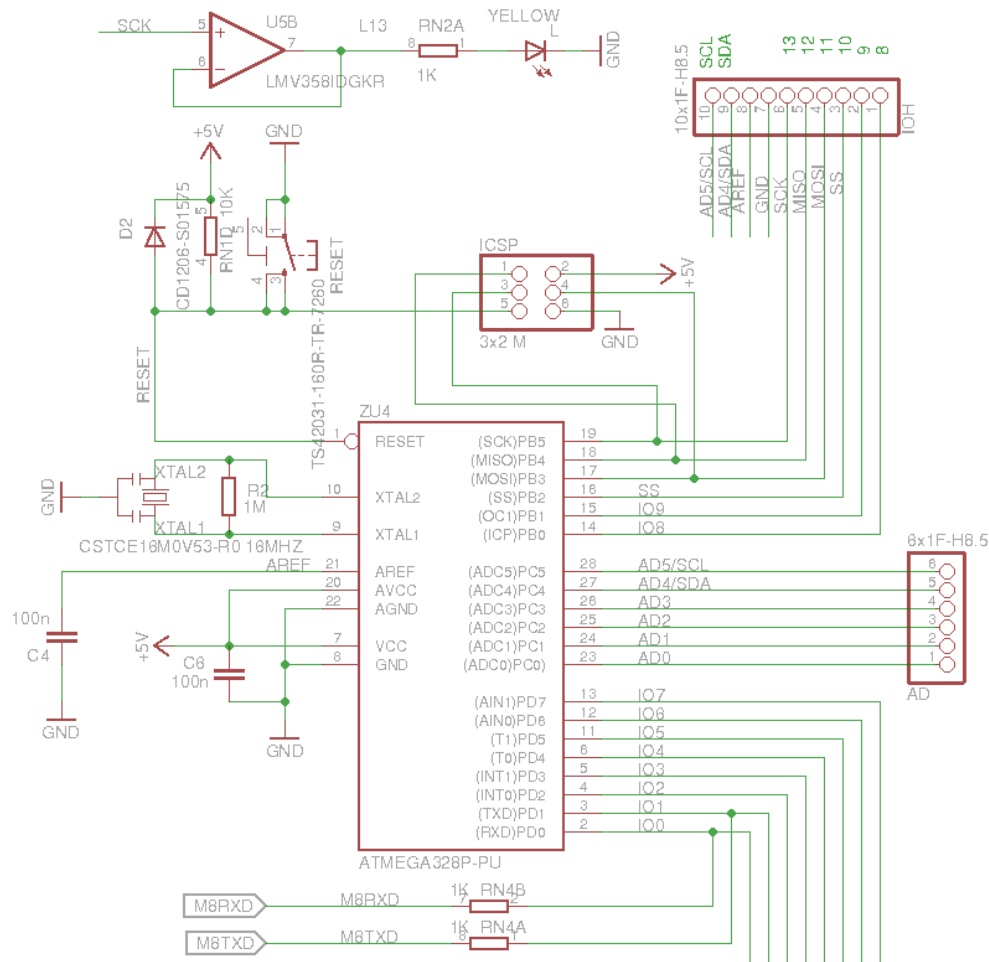
**Figure 8: Simplified Circuit Schematic for ATMega328P Evaluation Board [11]**

### 5. PROGRAM CODE

The following is an excerpt from the main source code. This section reveals the response when the sensors meet a certain condition. The three main sensors are in a loop. Therefore, they will keep running until the system is shut down. The order of the sensors is not important, as long as they are within the loop. Delays are introduced (line 50) to prevent repeated messages over a short period of time. As mentioned previously, the LM35 temperature sensor outputs raw data. Line 54 shows the formula for converting that data into degrees Celsius. In summary, this loop is mainly "if" and "then" statements. If an event occurs, then the device will respond with the appropriate action.

```
35   SIM900.println(message);
36   delay(100);
37   SIM900.println((char)26);
38   delay(100);
39   SIM900.println();
40   delay(5000);
41 }
42
43 void loop()
44 {
45   motionsensor_value = digitalRead(motionsensor_pin);
46   if (motionsensor_value == HIGH) {
47     delay(1000);
48     message = "Motion Detected";
49     sendSMS(number, message); // send sms
50     delay(15000);//wait 15 seconds until next motion.
51   }
52
53   temp_value = analogRead(temp_pin);            //read the value from the sensor
54   temp_value = (5.0 * analogRead(temp_pin) * 100.0) / 1024;
55   //Serial.println(temp_value); //monitor value of analog sensor in serial monitor
56
57
58   if (temp_value >= 40) {
59
60     delay(1000);
61     message = "High Temperature Detected";
62     sendSMS(number, message); // send sms
63     delay(15000); // wait 15 seconds until the next detection.
64
65     if (temp_value >= 10) {
66
67       delay(1000);
68       message = "Low Temperature Detected";
69       sendSMS(number, message); // send SMS
70       delay(15000);
71     }
72   }
73   flame_value = analogRead(flame_sensor_pin); //read the value from the flame sensor
74   Serial.println(flame_value);
75
76   if (flame_value < 1013) {
77     delay(1000);
78     message = "Fire Detected";
79     sendSMS(number, message); // send SMS
80     delay(15000);
81   }
82 }
83
```

## 6. CONCLUSION

Many systems and technologies are involved with smart housing including communication technology, IT systems, actuators and sensors. The devices powering smart homes are sensor-based and network-enabled. As technology advances, so does the IoT. In order to further enhance this project as a commercially viable system, more smart devices in the home are needed such as security cameras, central air systems, and even lighting systems to help guard against intruders and provide greater overall protection.

This system can be improved further by allowing the user to arm and disarm remotely by text message commands or by using an app. Moreover, connecting this system to the cloud further enhances the capability for the user to visually monitor the house with various data. While the

174

IoT has shown some vulnerability, when it is used correctly, the benefits provide peace of mind, along with a faster reaction time should an intrusion occur. One of the primary motivations in developing this project is to have a widely available and affordable system. Every home owner should be able to purchase and implement such intrusion and fire protection to prevent potential loss. This project demonstrates the cost effectiveness of using inexpensive and commercially available components from a wide supplier base.

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# Autonomous Package Delivery Drone

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## ABSTRACT

The project outlines the idea of creating a micro sized autonomous drone that is able to deliver a package using only onboard sensors and without the use of GPS for positioning and localization, as it is used in an indoor environment. As a part of American Helicopter Society International's Micro Air Vehicle Student challenge, the vehicle dimensions and weight are strictly followed and the drone is under 500 grams and no more than 450 mm in any dimension. In order to achieve these requirements, the frame is designed using CATIA and printed using PLA combined with carbon fiber tubes for increased strength. All electronic components are selected considering weight and power consumption. For the autonomous movements, MAVLink protocol is used for communication with the flight controller and ground control station. Along with this, DroneKit-Python API is used for sending movement commands and for the target search algorithm. To achieve the target search, OpenCV libraries are used.

## 1. INTRODUCTION

Over the past few years, the designs and applications of drones have changed significantly and increased rapidly. Companies such as Amazon, United Postal Service (UPS), and several others have started to experiment using a drone for faster package delivery. These companies have achieved few successful flights and plan to do a lot more testing in the future. The quad-copter designed in this project will be capable of delivering packages autonomously. The main goal of this project is to build, program, and design a drone that is safe, functional, and capable of performing the mission task. As a part of the American Helicopter Society International 2018 Micro Air Vehicle Student Challenge, the drone must be of a small scale and it must be lightweight. The frame of the drone will be designed using CATIA Computer Aided Design (CAD) software and will be 3-D printed. The quad-copter will incorporate multiple sensors capable of target detection and obstacle avoidance. Stress and strain analysis is performed on the designed frame using SolidWorks. The design shows success results for mechanical strength. The drone will also perform image recognition and autonomous flights using OpenCV and DroneKit-Python API.

## 2. SYSTEM ARCHITECTURE

The system architecture is shown below in the block diagram, Figure 1. The system is comprised of three main sections: the electronics, the frame, and the pickup mechanism. The electronics involves components which enable the drone to fly autonomously, control attitude, and control the pickup mechanism. The electronics section is further broken down into motors and speed controllers, vision and positioning sensors, and a flight controller. The frame incorporates the use of a 3-D printed center support body, motor mounts, and carbon-fiber rods. The mechanism involves a curved hook for pickup and drop-off of the package and a servo.
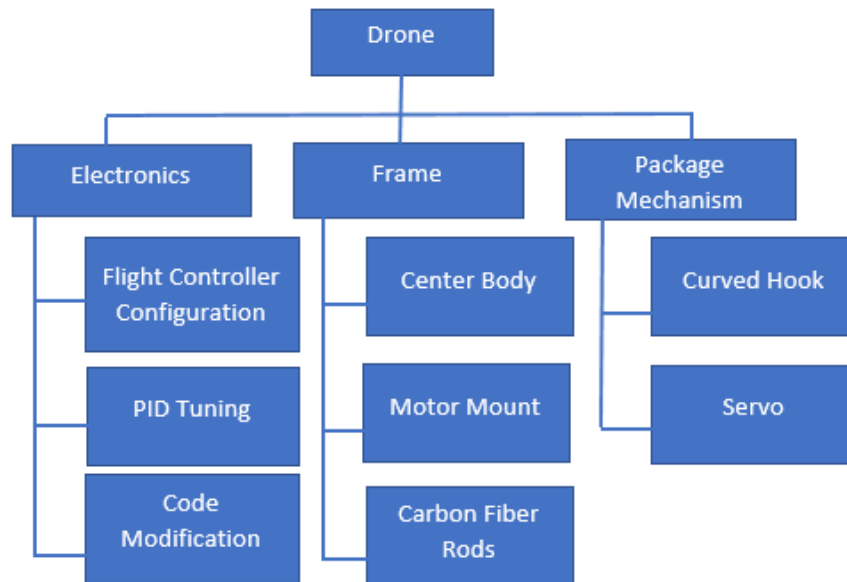


*Figure 1: System Architecture*

## 3. HARDWARE

### 3.1. FRAME DESIGN

For the frame, a quadcopter design was chosen due to its stability and maneuverability. The structure of the frame includes motor mounts, center support and a carbon fiber tube as shown in the figure. The motor mounts and center support are designed in CATIA and printed using Polylactic Acid (PLA) on the Ultimaker 3 Extended printer. Furthermore, the center support was designed to house components such as a flight controller, Battery, ESC, Lidar, Optical Flow and several other components. To make the frame light in weight, without compromising its strength, the frame was built using PLA and carbon fiber rods, instead of PLA only. To connect all the parts of the frame, the epoxy resin was chosen as it is lighter in weight compared to traditional nuts and screws. Epoxy resin is chosen, because it has a high yield strength of 3,500 psi, and it evenly dissipates vibration. Lastly, the carbon fiber tubes are made from weaved carbon fibers doped in resin. Four tubes connect all the motor mounts along with providing a mounting surface for the 3D printed center support. Carbon fiber tubes provide the necessary strength and rigidity to hold all the components of the frame together and reduce the vibration traveling from motors to the flight controller.

177

**Figure 2: Carbon fiber tubes**
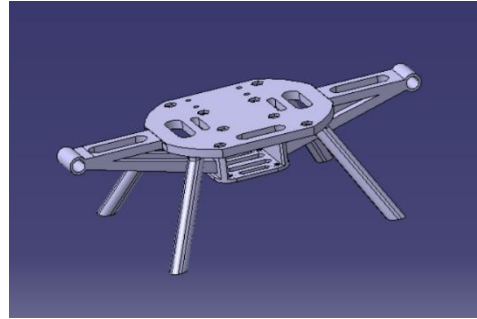


**Figure 3: Center Support**

Another component of the frame design of the quad-copter is the mechanism for the retrieval and delivery of the envelope package. The mechanism is designed to be lightweight and efficient to keep the drone under the weight limit of 500g.  The mechanism consists of a 3-D printed curved hook and a servo (Figure 4). The hook was built using CATIA and was printed using PLA on the MakerBot Replicator. The hook was designed to be curved so it will grab the ribbon on the envelope and prevent the envelope from dropping during the flight. It will be attached to an MS-R 1.3-9 OLIMEX continuous servo directly. Once the envelope is detected and the drone is at a certain distance from the ground, the servo is programmed to rotate up to certain angle, allowing the hook to grab on to the ribbon of the envelope.
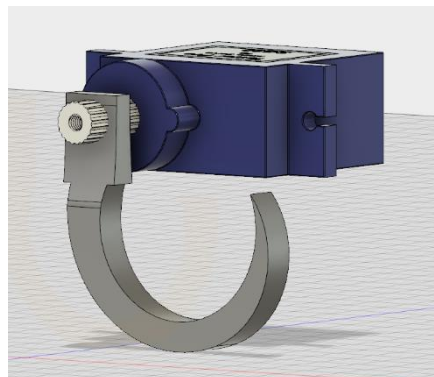


**Figure 4: Pickup mechanism**

## 4. ONBOARD SYSTEM

When selecting the motor, factors to consider include weight, power, efficiency, and torque, and the importance of each of these is ultimately determined by the methods we use to accomplish our goal. Ideally, we want our drone to fly efficiently, but also to generate enough thrust to achieve the task of the competition. Therefore, we will be using a brushless motor, since it is more powerful and efficient, and doesn't have the friction and voltage drop that the brushes create by dragging against the spinning commutator in brushed motors.

Efficiency is measured in grams/Watts, and motor efficiency can affect flight times, voltage consumption, and battery life. A higher KV motor tends to be more efficient when running at extreme speeds but at the expense of torque. If you apply 1 Volt to an unloaded motor, the KV constant tells you how fast the motor

178

will rotate [1]. Motor KV has nothing to do with the applied voltage. Instead, KV has to do with the back-emf. The motor KV constant is the reciprocal of the back-emf constant:

So Kv tells us the relationship between motor speed and generated back-emf.

$$K_v = \frac{1}{K_e}$$ 
(1)

The motor torque constant for brushed DC motors and brushless DC motors shows how current relates to torque [2]. As shown in the expression:

$$T = K_t * I$$ 
(2)

Where:
      $T$ = torque,
      $K_t$ = torque constant (Newton-meters per Amp)
      I = current.

$K_e$ and $K_t$ are actually the same constant. They are equivalent. This means that

$$K_t = \frac{1}{K_v}$$ 
(3a)

Another way of writing this is:

$$K_t * K_v = 1$$ 
(3b)

The formula to calculate Kv for brushless motors is:

$$K_v = \frac{Speed}{Volts * 1.414 * 0.95}$$ 
(4)

In order for the drone to achieve controlled flight, it needs to have enough thrust to lift off of the ground, hover, and maneuver in the air. For multi-rotor aerial vehicles, the rotor disk is generally oriented so that the force is called lift instead of thrust.

The following equations show the general thrust force equation used for the system. The velocity portion of the equation is the change in velocity across the propeller disk. The exit velocity is approximately the pitch speed of the propeller.

$$F_{lift} = \frac{1}{2} \frac{\rho \pi d^2}{4} (V_e^2 - V_o^2)$$ 
(5)

In order for the drone to have enough thrust to hover, the total weight of the drone has to equal the thrust force. However, the drone needs to also have enough thrust to lift off and maneuver. For an optimal flight, the build should be around 2:1 power to weight ratio [3]. The maximum lift, per individual motor, needs to be twice the weight of the drone, with variable N equaling the number of arms, as shown in the following equation:

$$Lift_{motor} = \frac{2W}{N} \tag{6}$$

The next equation involves finding the thrust loading and lift per individual motor and relating it to the power needed for each motor, while including an estimate for the efficiency, η, of the motor. The electrical power needed for each motor is calculated as follows:

$$P = Lift_{motor}/T_{Loading}\eta \tag{7}$$

For rough calculations, KV can be considered as the RPM/Volt (meaning, the speed at which the motor will turn per applied volt), but that will always be an approximation.

After looking at all the factors of the motor, we have decided to use Cobra CP 1407 Champion Series 3500KV brushless motor, which is light in weight and has enough power to complete the task of the competition. The stators are made with 0.20mm laminations for maximum efficiency and minimum Eddy Current losses. Since these motors are typically soldered directly to the speed controller to save weight, the CP-1407 motors come without bullet connectors, and feature extended pre-tinned motor leads. These motors also have 2mm threaded holes in a 12x12mm pattern on the back plate for easy installation on our quad-copter [4]. The Cobra motors have a continuous current draw of 16A with chosen propellers and battery; hence, the chosen ESC should be at least 25A for a factor of safety.



**Figure 5: Cobra 1407 3500kv motors**



**Figure 6: Lumenier 25A ESC**

The ESC (Electronic Speed Controller), controls the speed of the motors. The ESC receives throttle signal from the flight controller and drives the brushless motor at an optimally desired speed by providing the appropriate level of electrical power. Quality ESC's ensure a reliable and smooth flight experience. The first thing to look at when choosing an ESC is the current rating, which is measured in Amps. Motors draw current when they spin, and if the motor draws more Amps than what ESC can handle, then the ESC will start to overheat and eventually catch fire.

Due to the weight restriction for the competition, Lumeier Mini BHeli_S 4-in-1 25A ESC will be used. This ESC is very light weight, 14g, yet it is rated for current much higher than what the motors will draw. This ESC will be compatible with the chosen motors and will eliminate the risk of overheating due to excess current draw.

The flight controller chosen for the autonomous quad-copter is the Pixhawk 2.0. This is a 32-bit flight controller with a 10 Degree of Freedom board. This flight controller is chosen because it is the most used

flight controller by developers and also because it supports multiple types of connection for several sensors [5]. This flight controller supports MAVLink messages. MAVLink is a communication protocol supported by the communication between the flight controller and the single board computer. The Pixhawk also supports flight stacks like ArduPilot and PX4 which are the two most used flight stacks by all developers for a controlled flight.



**Figure 7: Pixhawk**          **Figure 8: Optical Flow (PX4 Flow)**

The PX4 Flow smart camera is a specialized monochrome camera module with a 3-axis gyroscope. It is used to detect ground texture and visible features by taking multiple pictures and comparing each picture with the previously taken picture [6]. The optical flow compares the features from the two pictures and combines the data with the internal gyroscope and Pixhawk's IMU to sense movement and bring it back to original position to achieve precise Position Control without the use of GPS. The camera was measured to weight a total of 19 grams.

In order to get the best flight time and performance, it is important to choose the right battery. The most commonly used battery for drones is a Lithium Polymer (LiPo) battery. The battery chosen for this quad-copter is a Multistar Racer 3S 1400mAh 40C LiPo Battery. In comparison to other batteries, this battery provides longer flight times and can discharge substantial amounts of power. It is also lightweight and has a higher power storage capacity and continuous discharge rate. As the capacity of the battery increases, the weight increases as well. For the competition, the drone is not required to have a long flight time, since there is a ten-minute time limit for the competition task.



**Figure 9: LiPo Battery**          **Figure 10: Raspberry Pi**
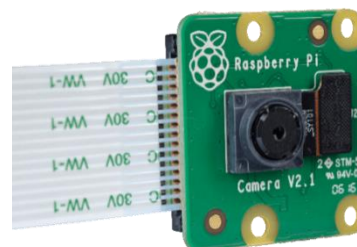
The USB camera chosen for this drone is Raspberry Pi camera v2.1 because of its weight and compact design. The Raspberry Pi camera is an extremely lightweight 8-megapixel camera which is used for image processing to detect the targets and the boundaries of the filed. This camera can be used to generate a matrix from the picture taken and analyze that matrix to find

the colors and features which will be used for image processing for target and border detection. It also supports the CSI interface which is supported by Raspberry Pi.



Figure 11: TFmini LIDAR     Figure 12: Receiver     Figure 13: 3DR Telemetry

The TFmini LIDAR is being used to detect the height of the quadcopter. The Benewake TFmini LiDAR is a small and lightweight LiDAR sensor weighing about 6 grams. It is used to measure the distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3-D representations of the target. This LIDAR is compact, lightweight, and has low power consumption, less than 1W. It has a refresh rate of 100 MHz and accuracy up to 7 meters, [7] enough for the competition. It also supports UART communication, which is supported by the Pixhawk.

For the transmitter and receiver, we are using FrSKY Taranis Plus which allows us to use 8/16 channels to program switches for multiple tasks like a kill switch or manual override as a safety feature. The total weight of the receiver was measured as 16.6 grams and it consumes about 100mA at 5V. 3DR Telemetry Radio 915 MHz has been chosen for this quad-copter to send and receive data to Ground Control Station, because it is one of the easiest ways to set up a telemetry connection between the Pixhawk and a ground control station. 3DR Telemetry Radio is a small, light and inexpensive open source radio platform that typically allows a range of over 300m. It uses open source firmware which has been specially designed to work well with MAVLink packets and to be integrated with the Mission Planner. The 915MHZ telemetry can be used to receive data from the drone in real time and can be analyzed in Mission Planner.

Another important part of the quadcopter is the Single Board Computer (SBC), in this case Raspberry Pi 3. This SBC has a 1.2 GHz 64-bit processor and has 1 GB of RAM which seems promising for the compute tasks needed for this competition. Raspberry Pi supports development environment, Linux flavor of Ubuntu Mate, which is used to program the quadcopter for autonomous movements [8]. This SBC also supports CSI connection which is what the Raspberry Pi cam uses.



**Figure 14: Raspberry Pi 3**

## 5. SOFTWARE

The software requirements for the project include choosing a flight stack, a single board computer, a development environment to run on the single board computer, target detection, and communication between different components. The process of vehicle autonomy includes selecting flight stack for performing a stable and controlled flight. Another part includes a development Application Programming Interface (API) which can be used to send commands to and from the flight controller depending on the live target search results.

## 6. VEHICLE AUTONOMY

### 6.1. FLIGHT STACK

Pixhawk is compatible to use with ArduPilot flight stack and PX4 flight stack. Both flight stacks have their pros and cons. ArduPilot flight stack is tested by developers and then made available for the users to upload to their flight controller. They also have a master firmware file which is available for developers to work on but is not recommended for normal users. PX4, on the other hand, is designed and maintained for the developers. This firmware has more features compared to the ArduPilot firmware and supports more advanced algorithms to use with the companion single board computer as well as with the flight controller. The builds for this firmware are unstable compared to the ArduPilot flight stack. Also, the users of this firmware are the developers, so they test fly using the newly developed code and report any issues, making changes as needed. For the application of the Autonomous Package Delivery Drone, ArduPilot flight stack is used, because it is managed by developers and the builds are more stable compared to the PX4 firmware.

### 6.2. MAVLINK COMMUNICATION PROTOCOL

Micro Aerial Vehicles (MAV) communication protocol is not limited to just aerial vehicles but can also be used by ground robots. This message consists of 17 bits of information that can be sent to the flight controller or received from the flight controller to the ground control station. It is designed as a header only marshaling library. The MAVLink messages are basically a stream of bytes that has been encoded by Ground Control Station software and is sent to the flight controller via USB serial or Telemetry connection. MAVLink also performs a checksum to make sure the message is not corrupted. In doing so, higher baud rate speeds are not achieved and are limited to a baud rate of 57000 over the Telemetry. While connected to USB, we are able to achieve speeds of up to 115200 [9]. This means compromising high-speed data updates on the ground station for minimal errors. MAVLink is a binary telemetry protocol designed for resource-constrained systems and bandwidth-constrained links. Telemetry data streams are sent in a multicast design, while protocol aspects that change the system configuration and require guaranteed delivery like the mission protocol or parameter protocol are point-to-point with retransmission. This makes the protocol reliable and usable for autonomous vehicles [10].

MAVLink has been deployed in two major versions - 1.x and 2.x. MAVLink 1.x was adopted by many developers for multiple applications. The transition from version 1.x to version 2.x is very smooth as version 2.x C/C++ and Python are backward compatible. In the application for the autonomous quadcopter, MAVLink v2.x is being used. To use the MAVLink commands, MAVLink has a version handshake check which checks if the MAVLink running on the ArduPilot stack on the quadcopter is

version 2.x or version 1.x, and an acknowledge command is sent back to the companion computer. If the acknowledge command is not sent back, this means the ArduPilot version cannot send or receive messages until upgraded to the compatible version [11]. This version check performed by a Ground Control Station (GCS) is illustrated in the figure 16.



**Figure 15: MAVLink Structure**          **Figure 16: MAVLink version check**
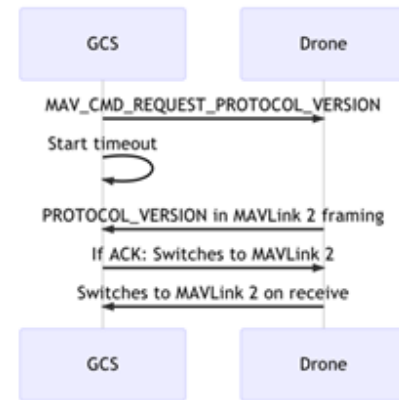
MAVLink consists of system id, message id, component id, and payload. For a message to be sent and accepted, the system id and message id are hardcoded to be the same for APM and PX4. The system performs a checksum of the system id and component id to execute any command. If this check fails, the command is rejected, and the next message is checked.

Some examples of Ground Control Station include Mission Planner, QGroundControl, and DroidPlanner. All these GCSs support MAVLink Communication protocol for data transfer. For Ground control station in this project, Terminal application, which is preinstalled with macOS, is used in combination with Mission Planner running on Windows environment.

### 6.3. DRONEKIT-PYTHON API

DroneKit-Python is an API for developers to create Python scripts to communicate with vehicles over MAVLink protocol. It provides developers with access to a vehicle's telemetry and status information, along with enabling both mission management and direct control over vehicle movement and operations.

It allows the user to develop on the drone itself, by accessing onboard companion computer, and it also supports high-level path planning, computer vision, 3D modeling and more [12]. All these tasks require intense computing power that the flight controller alone cannot handle. This is the reason why a companion computer is used alongside the flight controller. This way the flight controller can manage the flight computing for Proportional Integral and Derivative (PID) controls and Extended Kalman Filter (EKF) algorithms for a stable flight, while the companion computer can focus on the other tasks that require higher computing power like image processing. It can also be used to control drones from desktop computers and ground station apps, communicating easily over a higher-latency RF link. DroneKit supports the previously mentioned MAVLink commands to communicate with the flight controller to make the drone autonomous.

184

DroneKit-Python version 2.x is built from scratch to increase performance, ease of use, ease of development, extensibility, and testing. DroneKit-Python 2.x is designed to make the on-vehicle development process easier, more efficient and more robust all around.

MAVLink message called "SET_POSITION_TARGET_LOCAL_NED" is used for maneuvers in this project. This message can be called to send position, velocity and acceleration commands in x, y, and z-axis [13]. The user can select from different coordinate frames to send movements relative to the coordinate frame the drone was initialized in when it was turned on, or it can also utilize the coordinate frame based on North East Down (NED). For this project, "MAV_FRAME_BODY_NED" is used as the coordinate frame so that the movements sent are relative to the heading of the quadcopter when it was turned on. A simple take off script is shown here:

```python
#!/usr/bin/env python

from dronekit import connect, VehicleMode, LocationGlobal, LocationGlobalRelative,
from pymavlink import mavutil # Needed for command message definitions
import time
import math

vehicle = connect('/dev/ttyACM0', wait_ready=True)

def arm_and_takeoff(aTargetAltitude):

    print "Arming motors"
    # Copter should arm in GUIDED mode
    vehicle.mode    = VehicleMode("GUIDED")
    vehicle.armed   = True

    while not vehicle.armed:
        print " Waiting for arming..."
        time.sleep(1)

    print "Taking off!"
    vehicle.simple_takeoff(aTargetAltitude) # Take off to target altitude

    while True:
        print " Altitude: ", vehicle.location.global_relative_frame.alt
        #Break and return from function just below target altitude.
        if vehicle.location.global_relative_frame.alt>=aTargetAltitude*0.95:
            print "Reached target altitude"
            break
        time.sleep(1)

def send_ned_velocity(velocity_x, velocity_y, velocity_z, duration):
    """
    Move vehicle in direction based on specified velocity vectors.
    """
    msg = vehicle.message_factory.set_position_target_local_ned_encode(
        0,       # time_boot_ms (not used)
        0, 0,    # target system, target component
        mavutil.mavlink.MAV_FRAME_BODY_OFFSET_NED, # frame
        0b0000111111000111, # type_mask (only speeds enabled)
        0, 0, 0, # x, y, z positions (not used)
        velocity_x, velocity_y, velocity_z, # x, y, z velocity in m/s
        0, 0, 0, # x, y, z acceleration (not supported yet, ignored in GCS_Mavlink)
        0, 0)    # yaw, yaw_rate (not supported yet, ignored in GCS_Mavlink)

    # send command to vehicle on 1 Hz cycle
    for x in range(0,duration):
        vehicle.send_mavlink(msg)
        time.sleep(1)

arm_and_takeoff(1)

vehicle.mode = VehicleMode("LAND")
time.sleep(1)

vehicle.close()
```

*Figure 17: Simple Take off*

185

To keep safety in mind, a kill switch is also programmed using the transmitter to either gain manual control back or to completely cut power to the motors in case of an absolute emergency.

## 7. TARGET DETECTION

Target detection for the drone is being handled by OpenCV computer vision libraries [14]. The target detection algorithm uses features picked up from the ground to detect if the targets are present in the frame of the downward facing camera on the drone. The targets will be identified using recognition of different shapes present on the home base, drop-off, and pick-up location. The OpenCV libraries will be used to differentiate between the targets by using a circle and square detection. The target detection algorithm bases the circle and square detection on the difference between features of the image. The algorithm finds the different contours present on the ground and tries to approximate the curve using the least vertices possible. This results in the algorithm finding contours and shape with relatively high accuracy. The algorithm is further improved by running a color filter on the image and actively looking for black areas where the black rectangles for the drop off location will be located. Coupled with the color filter and the shape detection, the drone can find the pickup target accurately and can plot the center point on a grid based on the current frame. A similar method is used for circle detection for the targets. A Hough Circle Transform is used to detect circles in an image. To aid in determining either the drop-off or the home base, color filters are used to differentiate between the two targets.

Border detection for the drone is another important detection algorithm which needs to be precise for the drone to stay within the field boundaries. The reflective tape used as the border has reflective areas which are used to detect if there is a border. The drone will have a flashlight attached to the bottom which will illuminate the reflective tape and mark it as a white region in the camera frame. The border detection algorithm looks for these areas of similar intensity and pixels and identifies them as "blobs". These blobs are then filtered based on whether or not they have a specific area, how slant they are, and if they are convex. Based on all the filters, the algorithm can plot a line on the border and return x and y coordinates of the location of the border that is closest to the origin of the frame.
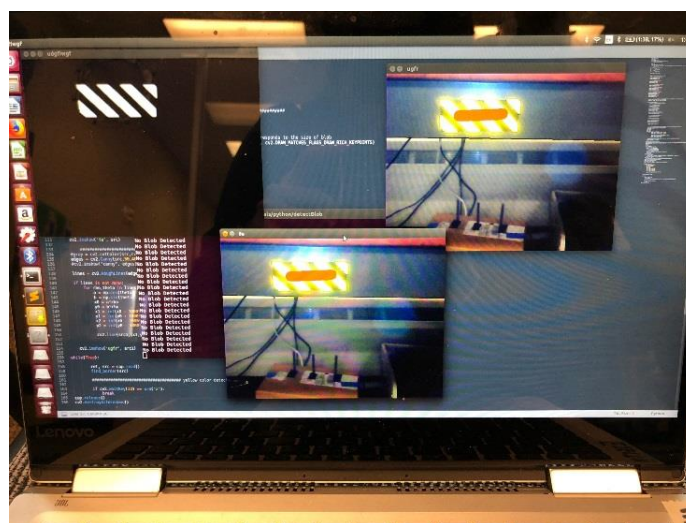


**Figure 18: Border Detection**

For the search algorithm, if the drone does not find any target in the camera frame, it will keep searching for the targets. Once the target is found the drone will try to align the X and Y coordinates of the frame with the X and Y coordinates of the detected target and land for pick- up or drop-off of the package.

## 8. CONCLUSION

The objective of this project was to develop an autonomous package delivery drone that can pick up and deliver an envelope as per the American Helicopter Society International Micro Air Vehicle Student challenge. In order to achieve this, the frame of the quadcopter was designed in CATIA with stress and strain analysis performed to check the strength of the design. The electrical components were chosen considering the weight and power consumption to make sure that the drone is under the weight limit of 500grams. When programming the quadcopter, after trying several different MAVLink messages, '*set_position_target_local_ned*' command was chosen, because using this command, position, velocity and acceleration commands can be sent for the target search algorithm. Using the available OpenCV libraries for computer vision, pickup and drop off targets and the border are detected to stay within the boundaries of the field.

## 9. REFERENCE

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**[2]** http://www.calvin.edu/academic/engineering/2014-15-team02/content/FinalReport(1).pdf
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**[7]** https://www.sparkfun.com/products/14577
**[8]** https://www.raspberrypi.org/products/raspberry-pi-3-model-b/
**[9]** https://diydrones.com/group/arducopterusergroup/forum/topics/mavlink-tutorial-for-absolute-dummies-part-i?xg_source=activity
**[10]** https://mavlink.io/en/protocol/overview.html
**[11]** https://mavlink.io/en/mavlink_version.html
**[12]** http://python.dronekit.io
**[13]**http://ardupilot.org/dev/docs/copter-commands-in-guided-mode.html#set_position_target_local_ned
**[14]** https://opencv.org

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# Mechanical Design of an Exoskeleton

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## ABSTRACT

Throughout the years, researchers have been inspired by science fiction books and movies to make an effective exoskeleton. For this project, an exoskeleton is an active mechanical device, anthropomorphic in nature, that the person can wear and use as an assistive device. It's a wearable exoskeleton for supporting the arm and transferring a load from the arm to the ground. This exoskeleton is equipped with a locking mechanism and mobility assistance without adding additional burden to the human body. Exploiting biomimetic design, the device may be worn near the body and transmit torques via unpowered revolute joints and structural limbs. To this day, unpowered upper and lower body exoskeletons have not been developed sufficiently for public use. Previous exoskeleton development has largely been part of major research endeavors and has produced only high inertia limbs, which are burdensome to the wearer. The goal is to make this sophisticated technology accessible to a large population, by designing an exoskeleton capable of lifting moderate to heavy loads. Robust mechanical design, novel actuation methods, and embedded systems were integrated to create the exoskeleton. The solution involves a series of controllable limbs such as an unpowered elbow joint, containing two unpowered rotational joints at the shoulder. This exoskeleton offers a solution that may be extended to accessible exoskeletal systems for use in assisting human mobility in lifting heavier loads and increasing the limb and joint function levels. This project involves exoskeleton CAD modeling, constructing a prototype, and CATIA programming used for drafting and implementing a necessary stress analysis. Furthermore, Microsoft Project Management is used for cost and scheduling, and Microsoft office for documentation and presentation.

## MOTIVATION

A strong, flexible exoskeleton allows workers to perform physical work and bear external loads. The exoskeleton should enable workers to perform these jobs comfortably and efficiently, without fatiguing their muscles. The risk inherent in performing this type of work is injury and long-term damage to the health of the joints and supporting muscles, injuries that can reduce the individual's future quality of life.

188
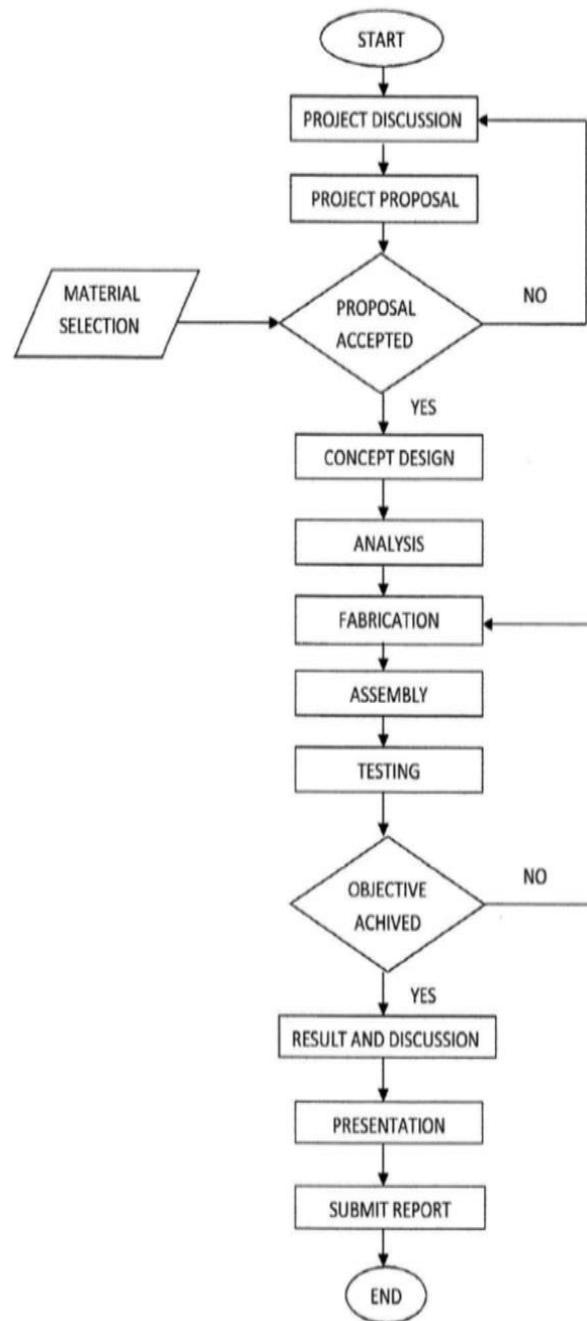
**Project Process**



Chart 01: Project plan

The project plan is the process of planning, organizing and managing allotted resources given to a project in order to successfully complete the project's objectives and program.

## INTRODUCTION

Exoskeletons, a hard shell supporting the internal organs, exist in the natural world in a variety of species such as insects and reptiles. Such a shell protects these species against the harsh environment and predators. Since the second half of the 20th century, researchers became interested in adapting the exoskeleton for human operators. The exoskeleton unites man and machine, by providing the complementary traits that neither possesses. While the machine provides massive strength and endurance, the human provides flexibility, intellect, and versatility to the performance of a required task. The first robotic exoskeletons were developed for use in industrial environments (General Electric, 1969) in which they were capable of lifting and operating heavy machinery that otherwise would be difficult and inefficient for manual labor. As technology progressed, the introduction of computerized control systems and shrinking actuators allowed machines that were once gigantic to become much smaller and to take on much more lifelike dimensions. Once conceived only in science fiction, these new control systems now allowed new possible applications. Giant industrial exoskeletons still retain fascination of scientists, and today they are developed primarily for military use (Ernst 2017) or as an aid to rehabilitation. Some particularly mobile versions are even used to enhance the quality of life for those affected with an ambulatory disability, providing the assistance required for one to move about. However, in spite of the numerous engineering challenges that have been resolved by GE at Texas Tech University, the exoskeleton is a technology that is still in its infancy. There are many fundamental problems that remain open and needed to be resolved in order for the exoskeleton to reach its full potential. As each problem is solved, a deeper layer of complexity is revealed [1].

The exoskeleton, a literal union of man and machine, combines the brute force and endurance of a machine with the dexterity, intellect, and versatility of its human operator to perform tasks not possible by either acting alone. Exoskeletons have enormous potential for heavy industries and have become an integral part of increasing the users' level of endurance.

## CLASSIFICATION AND MECHANISM

The exoskeleton in this study is a passive one that does not have any electrical power source. That passive exoskeleton has a Locking Mechanism, designed to be unobtrusive, until it is locked into place, allowing the user to work in the same position for a prolonged period [2]. This exoskeleton works to re-distribute weight, through locking mechanisms that divert the weight of an object around the user and into the ground.

## DESIGN OF WORK

This case study aims to design and develop a full-body exoskeleton. In a production line, workers manually lift moderate and heavy weights for long periods of time, causing stress and fatigue to their body. The three machines required to create this system are the drilling machine, the arc welding machine, and the grinding machine. All three machines will be explained later in the experimental procedure. We conducted investigations and performed some calculations before designing the product. These calculations identify the accurate position to place the damper on the main body and the required angle. Finite element analysis will also be performed to find the maximum weight that the product can accommodate.

190

## Mathematical Formulation:

### Moment, direction and magnitude around the hip:

Equation 1 indicates the moment around the hip, which is effected by both forces R and W. $\vec{r_w}$ is the distance from the hip to the end of the arm and $\vec{w}$ is weight carried by the arm. Equation 2 indicates the direction of the resultant moment around the axis. Equation 3 is the magnitude of the moment in the three directions.

$$\vec{M_H} = \vec{r_w} * \vec{w} \tag{1}$$

$$\alpha = \tan^{-1}\left(\frac{y(\hat{\jmath})}{x(\hat{\imath})}\right) \tag{2}$$

$$|\vec{M_H}| = \sqrt{(x)^2 + (y)^2 + (k)^2} \tag{3}$$

### Von Mises equation principal stresses:

The von Mises yield criterion suggests that yielding of a ductile material begins when the second deviatory stress invariant reaches a critical value. It is part of plasticity theory that applies best to ductile materials, such as some metals. Prior to yield, material response can be assumed to be of a nonlinear elastic, viscoelastic or linear elastic behavior.

$$\sigma_v = \sqrt{\frac{1}{2} \cdot (\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2} \tag{4}$$

### Engineering Strain: (displacement)

The engineering strain is expressed as the ratio of total deformation to the initial dimension of the material body in which the forces are being applied. The engineering normal strain or engineering extensional strain or nominal strain e of a material line element or fiber axially loaded is expressed as the change in length $\Delta L$ per unit of the original length L of the line element or fibers.

$$\epsilon = \frac{\Delta L}{L} = \frac{l - L}{L} \tag{5}$$

### Bending Stresses in Beams:

The bending moment, M, along the length of the beam can be determined from the moment diagram. The bending moment at any location along the beam can be used to calculate the bending stress over the beam's cross section at that location. The bending moment varies over the height of the cross section.

$$\sigma = \frac{Mc}{I} \tag{6}$$

**Maximum deflection on beam:**

$$\delta_{max} = \frac{pl^3}{3El} \qquad (7)$$

## WORKER DIFFICULTIES AND THE NEED FOR AN EXOSKELETON

Lifting and Material Handling - Lifting heavy items is one of the leading causes of injury in the workplace [3]. Strains and sprains from either improperly lifting loads or carrying loads that are either too large or too heavy are common hazards associated with manually moving materials. Manual handling of loads may lead to cumulative disorders due to gradual and cumulative deterioration of the musculoskeletal system through continuous lifting/handling activities. In other words, the worker may experience low back pain.

Lifting and carrying loads and workplace injury - Lifting and carrying loads is the major cause of work-related lower back problems. The muscular effort in lifting and carrying depends mostly on the Weight of the load and the Distance of the center of gravity of the load from the body. Therefore, the heavier the load and the further away the load is from the body, the greater the muscular effort needed to handle such load [4]. For example, a 4 kg weight held at a distance of 50 cm requires the same effort as a 20 kg weight held close to the body.

## ENGINEERING REQUIREMENT

**Free Body Diagram and stress analysis:**
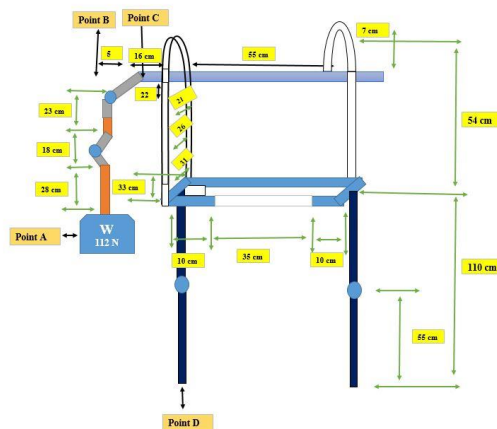


**Figure 1: Creation of the geometric full body Exoskeleton**

Free body diagram Figure 1 is a graphical illustration used to visualize the applied forces, movements, and resulting reactions on a body in a given condition. They depict a body or connected bodies with all of the applied forces and moments, as well as reactions that act on that body.

192

**Free body diagram for the exoskeleton when the load at 0°**
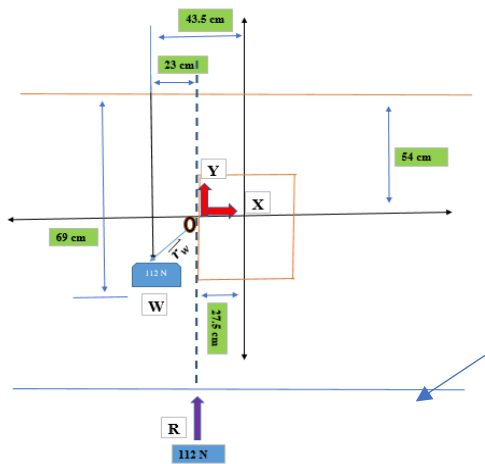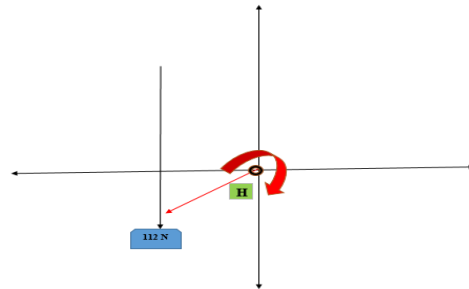


Figure 2a                                          Figure 2b

Figure2 (a &b) involve creation of the geometric full body Exoskeleton when carrying load of 112N at **0°**,

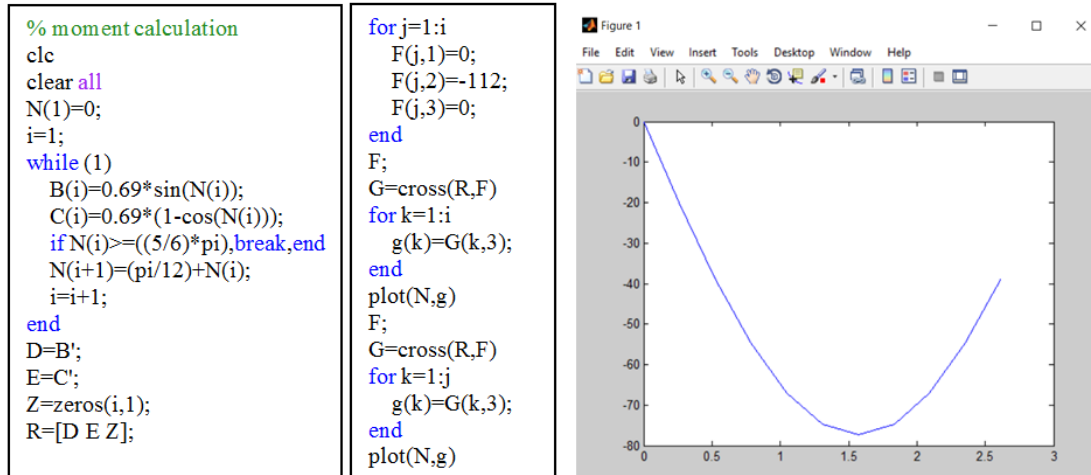**Case 1 shows when the load downward the ground ($\theta = 0^o$)**

Figure2 (a&b) indicates one side of the exoskeleton that carry a load of 112 N which equals to 25 lb. R is the reaction at the ground which is equal to the weight (W=112 N) and pointed upward opposite to the weight. $\overrightarrow{r_w}$ is the distance from the hip to the end of the arm. $\overrightarrow{M_H}$ Is the moment around the hip, which is affected by both forces R and W and it is equal to 25.76 N. m in $\hat{k}$ direction.

**Free body diagram for the exoskeleton with the load at 90°**
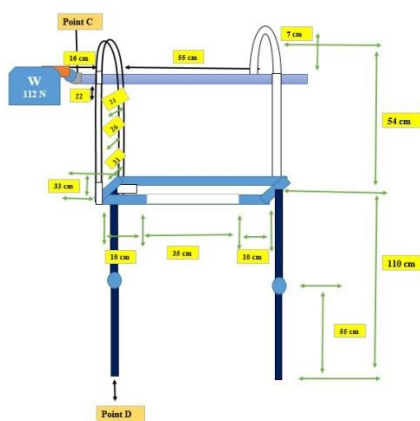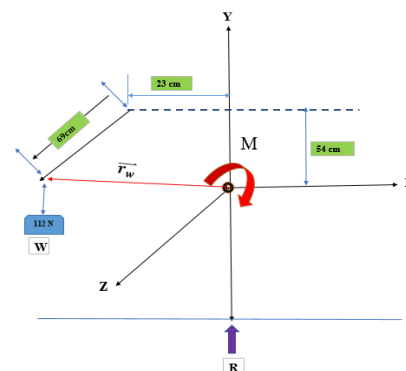


Figure 3a                                          Figure 3b

Figure 3 (a&b) involve creation of the geometric full body Exoskeleton when carrying load of 112N at **90°**

193

**Case 2 shows when the arm carries the load at $(\theta = 90^o)$**

Figure 3 (a&b) show one side of the exoskeleton that carries a load of 112 N which equals to 25 lb. R is the reaction at the ground which is equal to the weight (W=112 N) and pointed upward opposite to the weight. $\vec{r_w}$ is the distance from the hip to the end of the arm and equal to $-0.23\,\hat{\imath} + 0.54\,\hat{\jmath} + 0.64\,\hat{k}$. $\overrightarrow{M_H}$ Is the moment around the hip, which is affected by both forces R and W and it is equal to $-77.28\,\hat{\imath} + 25.76\ N.m\ \hat{k}$

**Free body diagram for the exoskeleton with the load at 150°**
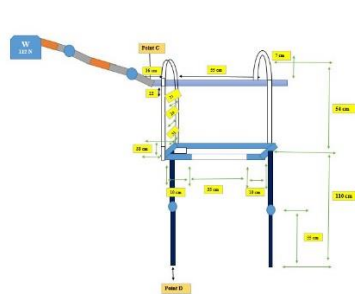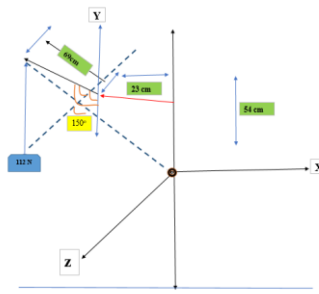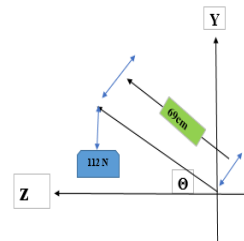


| Figure 4a | Figure 4b | Figure 4c |

Figure 4 (a, b, &c) involve creation of the geometric full body Exoskeleton when carrying load of 112N at **150°**

**Case 03 shows when the arm carries the load at $(\theta = 150^o)$**

Figure 4 (a, b, &mc) indicate one side of the exoskeleton that carries a load of 112 N which equals to 25 lb. R is the reaction at the ground which is equal to the weight (W = 112 N) and pointed upward opposite to the weight. $\vec{r_w}$ is the distance from the hip to the end of the arm and equal to $-0.23\,\hat{\imath} + 1.1375\,\hat{\jmath} + 0.345\,\hat{k}$. h is the distance from the point which carries the load to the z-axis and it is equal 0.5975 m. $\overrightarrow{M_H}$ Is the moment around the hip, which is affected by both forces R and W and it is equal to $\hat{\imath}\,(38.64) - \hat{\jmath}\,(0) + \hat{k}\,(25.76)$.

**RESULT**

Case 1, 2 and 3 demonstrated the effect of carrying load on the hip at different angles (0°, 90° and 150°). The results showed that at a 0° angle, there was minimal effect at the hip (case 1). The magnitude reached its maximum at a 90° angle due to longest distance of carrying the load away of the hip. Beyond the 90° angle, the effect of carrying on the hip reduced because of the decreased distance (case 3).

**MATLAB CODE:**

In figure (5) the graph that was devolved from MatLab code, and it was used to visualize quantitative data showing the relationship between the loads and the distance from the hip in different angles of the locking mechanism.

194

```
% moment calculation          for j=1:i
clc                              F(j,1)=0;
clear all                        F(j,2)=-112;
N(1)=0;                          F(j,3)=0;
i=1;                          end
while (1)                     F;
    B(i)=0.69*sin(N(i));      G=cross(R,F)
    C(i)=0.69*(1-cos(N(i)));  for k=1:i
    if N(i)>=((5/6)*pi),break,end  g(k)=G(k,3);
    N(i+1)=(pi/12)+N(i);      end
    i=i+1;                    plot(N,g)
end                           F;
D=B';                         G=cross(R,F)
E=C';                         for k=1:j
Z=zeros(i,1);                     g(k)=G(k,3);
R=[D E Z];                    end
                              plot(N,g)
```



**Figure: 5 MATLAB Code**

The MatLab Code that was created using actual loads and measurements showed that the theoretical analysis and calculation are matched with the result of the MatLab Code.

## CATIA CAD modeling and building a prototype of exoskeleton



**Figure 6a:** The fron view of the exoskeleton
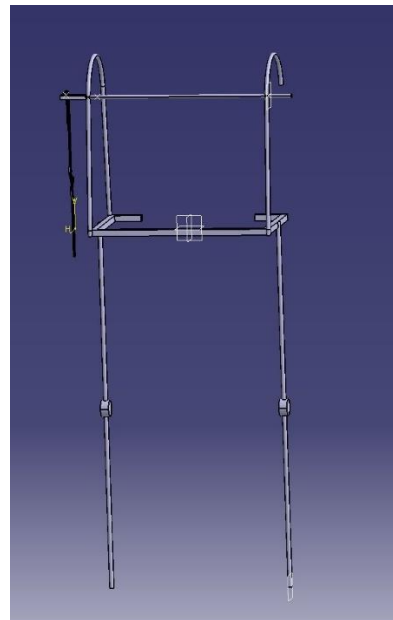


**Figure 6b:** The back view of the exoskeleton

195
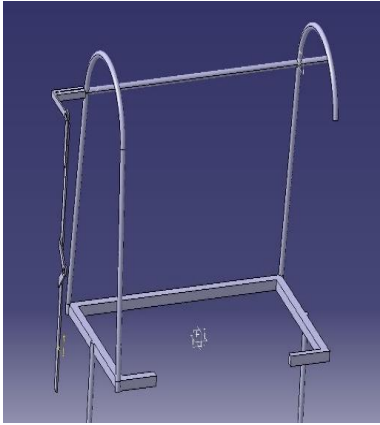
**Figure 6c:** The upper part of the Exoskeleton
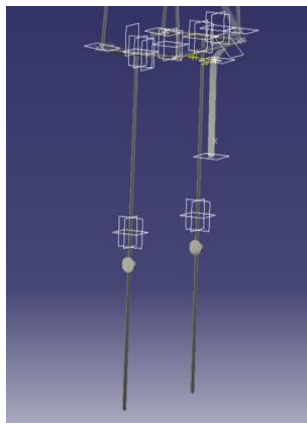
**Figure 6d:** The lower part of the exoskeleton
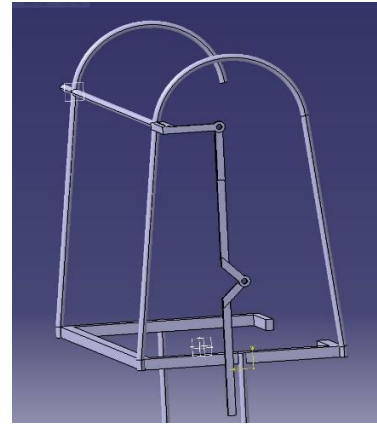
**Figure 6e:** The side view of the exoskeleton

The design was implemented using Catia CAD; Figure (6:a) shows the front view of the full body Exoskeleton, and (6:b) shows the back viewof the Exoskeleton. Figure (6:c) shows the upper part of the Exoskeleton, which includes shoulder and arm. Figure (6:d) shows the lower part of the Exoskeleton, which includes the waist and the legs. Figure(6:e) shows the upper part (side view) for the arm and locking mechanism.

**CATIA-Finite Elements Analysis**
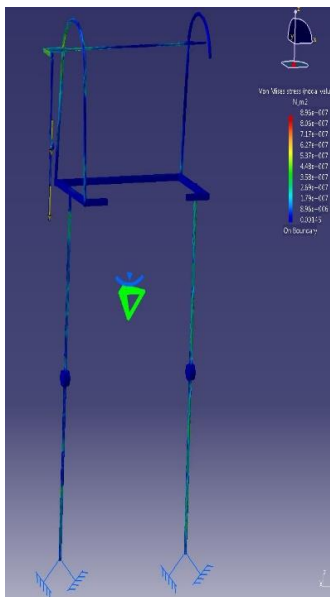


**Figure 7a:** The maximum stress
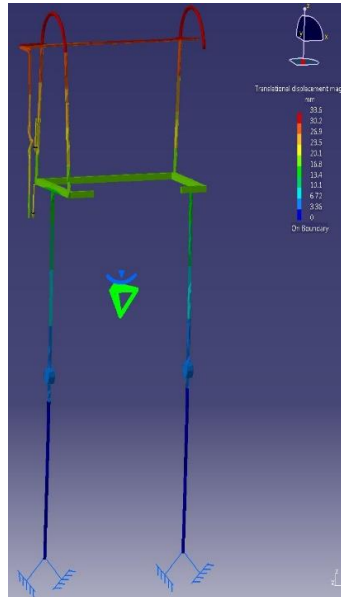
**Figure 7b:** The displacment
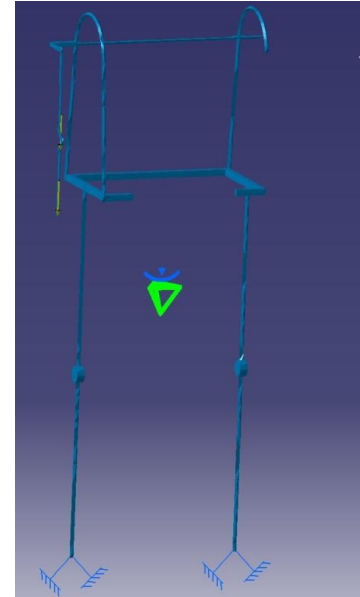
**Figure 7c:** The deformation

CATIA-Finite Elements Analysis was used for showing the stress analysis; the maximum stress, displacement, and the deformation. The maximum stress was distributed at the shoulder and both

196

legs, Figure(7:a). the displacment was located at back support and side vertical support Figure(7:b). the deformation was located at legs and back and side vertical support Figure(7:c).

**The Actual Prototype and the experiments**



**Figure 8a:** The model is wearing the exoskeleton while carring the load at 120 degrees (front view)

**Figure 8b:** The model is wearing the exoskeleton and bend while carring the load (back view)

**Figure 8c:** The model is wearing the exoskeleton while carring the load at 0 degrees (front view)



**Figure 8d:** The model is wearing the exoskeleton and bend while carring the load at 45 degrees (side view).

**Figure 8e:** The model is wearing the exoskeleton while carring the load at 90 degrees (front view).

Figure 8 (a, b, c, d, and e) are showing a worker wearing the exoskeleton and performed a test of the exoskeleton at all angles while carrying a load.

197

## CONCLUSION

The present work of the exoskeleton is intended to support the arm and transfer the load from the arm to the ground. The locking mechanism helps to carry the loads instead of the human working arm. This wearable prototype exoskeleton reduces the risk of human injury and the worker's level of endurance, thereby increasing work productivity. As a result, each worker will greatly increase his or her production. The exoskeleton achieves its goal, which is to carry the load more efficiently than a human.

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# Concepts of Mechatronics in Maritime Life Aquariums

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## ABSTRACT

One of the most time-consuming tasks for an aquarium is the maintenance of its subaquatic viewing panes. For smaller tanks, a scrubbing brush is used to remove algae and other animal residue. This forces aquariums to pay for more labor, as this manual task takes a lot of time and effort. For larger exhibits, however, drivers are suited with scuba equipment and must manually scrub the tanks from the inside. The objective of this project is to design a submersible, autonomous marine exhibit robot for the purpose of cleaning the glass panes within a commercial tank. This product will eliminate the need for manual scrubbing and ensure an overall cleaner tank for the animals inside. The submersible's user interface will be employed to input the dimensions of the marine exhibit. Within those parameters, the robot will clean the tank without human intervention. If necessary, however, the submersible will be easily accessible at its homing dock at the top of the tank.

**Keywords:** Submersible, Automated, Commercial Marine Habitat

## 1. INTRODUCTION

Algae are a form of plant life that is known to grow in marine habitats. Water, sunlight, and essential nutrients are a necessity for its growth [1]. Algae growth in moderation does not affect marine life. In fact, some fish are known to eat it. However, if left unchecked, algae can grow to a harmful level and become hazardous to fish and plant life. Reducing light and the quantity of food placed into the tank can limit algae growth, but this is not always a feasible solution. In addition to algae build up, watermarks, bacteria, and other fish residue can cling to fish tank walls. For this reason, tools such as Algae Pads, scrapers, and razor blades are traditionally used to clean the inside viewing glass on marine habitats.

199

The objective of this project is to model and prototype an autonomous, submersible device with the ability to attach to and clean a pane of glass. The submersible's computer interface allows tank dimensions to be easily uploaded to the robot, ensuring that the cleaning patterns are unique to the marine habitat. A homing dock is also mounted on the top of the tank so that the submersible can be easily retrieved for maintenance. The homing dock and submersible are also tethered together with a steel cable to ensure the two mechanical components do not detach.

In the commercial tank industry, aquarium magnets, as seen in Figure 1, are a commonly used method for cleaning tank walls. The scrubbing side of the magnet is placed on the inside of the marine habitat, and the magnetic handle is left on the other. The attraction between the different polarities pull the two pieces together, forming a magnetic cleaning brush. The felt that covers the magnets provides a buffer between the two halves and the tank. It also prevents scratching and is an effective way to scrub most marine habitats. With an aquarium magnet, the user can manually move the scrubber without having to remove any part of the tank. Its design also allows it to be left on the sides of any marine habitat for convenient use. This device is small and lacks time efficacy with large tanks, but works very well if only a small portion of the tank requires cleaning.

**Figure 1: Aquarium Magnet**

**Figure 2: Scuba Diver Cleaning Commercial Fish Tank Scrubbing Brush**

Although aquarium magnets are known for their high-quality cleaning abilities, when large commercial tanks require cleaning of the entire tank extended scrubbing brushes and scrapers, commonly used in residential tanks or smaller commercial tanks, aren't long enough. At this point, the choice of action is usually for Scuba Divers to manually clean the tank from the inside, seen in Figure 2. As a result, a wetsuit, fins, scuba tank, regulator, mask, and snorkel must be purchased. A Buoyancy compensator and weight belt are also needed to aid in ascent and descent within the tank [3]. The diver must also take training courses, be a certified scuba diver, and enter the tank with a diving partner. This solution is expensive because of the equipment needed, the maintenance of that equipment, and the laborers required to perform these cleaning tasks. The process itself is also long and involves a lot of manual labor and mental awareness in potentially dangerous, underwater surroundings.

200

**Figure 3: The RoboSnail Cleaning a Marine Habitat**

After its release, the RoboSnail, seen in Figure 3, became the first autonomous marine habitat cleaner in 2016. Currently, there are two available sizes on the market. The first ranges from 55-125 gallons with a glass thickness up to 10mm, whereas the second ranges from 55-180 gallons with a glass thickness up to 12mm [4]. The RoboSnail contains over ten sensors and is programmed to clean every 24 hours. The size of the marine exhibit is saved to the robot by allowing it to run laterally down the tank, pressing the central drive unit an inch before the floor bed, and then allowing it to back up the tank an inch before the top, again hitting the main drive unit. If the user would like to rerun it before it is programmed to run, the user can merely holding down the Main Drive Unit button of the front of the RoboSnail. The RoboSnail also features a rechargeable battery that is magnetically charged through its docking station. It is, however, limited to the front pane of glass and a 30-minute run time. Although this is a step in the right direction for the cleaning process of larger tanks, this device lacks the specifications to clean commercial aquariums.

These current marine tank cleaning techniques were all taken into consideration when it came to the design of the submersible fish tank cleaner. Its design will overcome the drawbacks of current scrubbing methods and provide a simpler solution for marine tank maintenance within the commercial tank industry. The current design of a commercial tank cleaner was created using a combination of a homing dock, scrubbers, and autonomous capabilities.

**2.0 DESIGN**

The task at hand was to create an autonomous solution to the cleaning process of commercial marine tanks. The robot was designed to move along a viewing pane while simultaneously cleaning it. The submersible has the ability to ascend and descend tank walls and move both left and right. Additionally, in order to prevent harm to the aquatic life within the tank, the device does not detach from the wall at any point during the cleaning cycle or while still active. The cleaning system consists of removing algae and other problem organisms from the pane in question. The system being designed should thus not physically or chemically harm the marine life within the exhibits being cleaned. To fulfill this requirement, the vehicle was designed with a software failsafe to shut off, detach, and return to its homing dock if any process goes wrong. Only non-toxic materials are brought into contact with the animals and plant life within the habitats. The submersible is easily accessed and maintained through the use of its homing dock, which aids in the ascent and the descent of the autonomous robot. The submersible, when it is not in use, is conveniently stored in its homing dock.

201

## Maximum Pressure Threshold

The amount of pressure experienced underwater is equivalent to:

$$P = \left(\frac{d}{10} + 1\right) * 14.5 \; psi \tag{1}$$

$$Where \; P = Pressure, d = distance \; submerged \; in \; water$$

The amount of pressure the robot can experience is dependent on the compressive force of the materials used. In this case, the most important materials are the FlexSeal and the PLA filament used to construct the robot. MakerBot reports an average compressive strength of their PLA filament to be approximately 2600 psi. However, this assumes a solid value throughout. Instead, the parts were printed with a 20% hexagonal infill, which likely assumes the compressive strength to be cut by said value:

$$New \; Makerbot \; Compressive \; Strength = 2600 * .2 = 520 \; psi \tag{2}$$

FlexSeal is stated to have a tensile strength of 485 psi, and a compressive strength of 59 ksi (when dried only, behaves like a viscous liquid before reacting to oxygen). Considering the far higher compressive strength between FlexSeal and PLA filament, it can be assumed that if the PLA can handle the pressures introduced by the tank, the FlexSeal can also handle the pressures.

## Maximum Depth Threshold

Thus, the maximum depth the robot can traverse is dependent on the water above the robot causing pressure. Using our previous equation 1 and the maximum strength (also referring to a value for pressure) from equation 2, we can find the maximum value for depth:

$$520 = \left(\frac{d}{10} + 1\right) * 14.5 \; psi => d = 348.621 \; meters \tag{3}$$

Currently, the largest commercial tank is the Whale Shark exhibit in the Chimelong Ocean Kingdom, with a viewing pane that is 39.6 meters wide by 8.3 meters tall. This 8.3 meters is far below the maximum depth value, so a robot constructed from PLA and FlexSeal should pose no problem to smaller tanks.

## Minimum Suction Force

To create a suction force, all water has to be removed from beneath the robot. Following the principle that a certain mass has to be removed from the robot internals, we first need to calculate the mass of the water under the robot.

$$V = 30.48cm^2 * {\sim}3.81 \; cm = 3539 \; cm^3 => m = 3.539 \; kg$$

$$where \; V \; is \; the \; volume \; under \; the \; robot, and \; m \; is \; the \; corresponding \; mass \; in \; water$$

The T200 thruster is capable of outputting a 5.1 kgf of thrust at maximum values, which would be enough to move the mass out of the way. However, it is inefficient to use such power at all times, so using documentation given to us by Blue Electronics, the most efficient PWM value to create this thrust can be found:
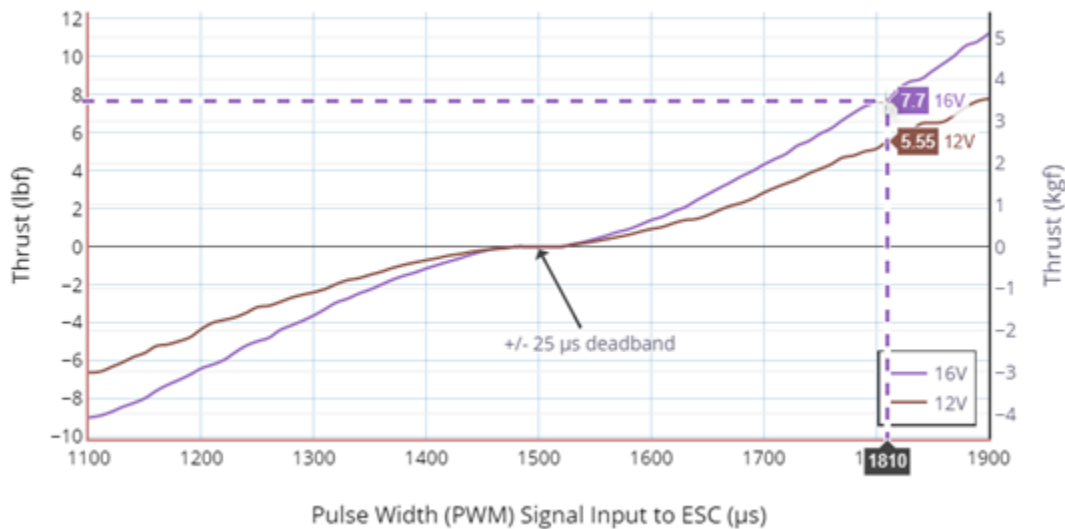


**Figure 4: Calculated most efficient value for mass requirements**

## 2.1 MOBILITY

To meet the needs, it was decided that the movement system would be limited to two degrees-of-freedom; a vertical direction as well as a horizontal. It was also established that there would not be any intended movement along a z-axis or any rotational other than to correct errors in movement through external forces. For the movement of the robot along the wall, the vehicle will make use of Omni wheels (as seen in Figure 5). The wheels will be driving the horizontal movement while also allowing vertical movement due to the nature of their design. For vertical movement, a tether system, as seen in Figure 6, will be implemented to compensate the weight of the robot. The weight and density of the vehicle itself provides its downward movement, and the tether allows for both a controlled descent and ascent.



**Figure 5: Omni Wheel**



**Figure 6: A steel cable winch will be used to tether the robot for vertical movement**

203

## 2.2 FRAME

The autonomous submersible features a box and hinge design, a system which allows for easy access to the interior of the robot, in the event of a malfunction. The robot was designed in Catia (Figure 7) to be one foot by one foot with a height of three and a half inches. A pocket was made to accommodate the T200 Thruster, which allows the robot to stay pressed against the wall. Holes were drilled along the sides of the robot to install lasers and photoresistors, which are used to detect the distance from the wall to its body. The frame is designed to house its waterproofed electronic components in its hollowed interior. Additionally, the frame is designed around the wheels and axles. These parts are not water sensitive, so they are designed to stay outside of the submersible's body.

To better dissipate the water flow emitted from the thruster, a spoiler was designed to attach to the main body. The suction generated from the T200 Thruster forces the submersible's body to cling to tank walls. However, the outtakes created were seen as a possible disruption to the surrounding marine life. To compensate for this problem, a spoiler was added as an attachment to the frame to help reduce the outtake directly into the environment.

The spoiler is designed to disperse the outtake radially so as not to create powerful underwater currents in any one direction. Vents added at the top of the spoiler were also created to prevent the part itself from being forcefully removed by the T200 Thruster. The spoiler was attached to the fan, as seen on the frame in Figure 7.
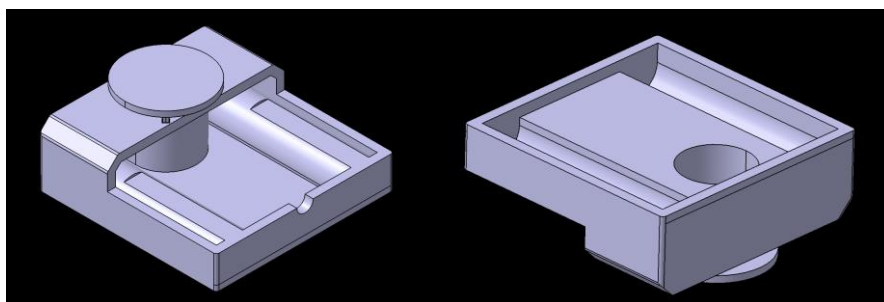


**Figure 7: Above and underside views of the CATIA-created model, with the spoiler attached and lid removed.**

The entire frame was coated with a sealant called FlexSeal. FlexSeal is a liquid rubber which, when applied to surfaces, acts as an adhesive between coated parts. Additionally, FlexSeal is waterproof. Because of this, it effectively protects the electronic components it surrounds. It also prevents water from entering the walls of the submersible, thus restricting the growth of bacteria within. The frame was designed and 3D-Printed using PLA and evenly coated with the FlexSeal is ensure its highest performance. FlexSeal is also non-toxic, versatile, and unaffected by extreme hot or cold temperatures. These factors are important to consider, because marine environments require varying temperatures depending on the requirements of the aquatic life inside.

Epoxy Marine was used to seal the frame and electronic components inside and outside of the robot's body. Epoxy Marine is a two-part system consisting of an epoxy resin and a hardener.

204

When the two substances were mixed together in equal volumes, the chemical reaction of the two produced a tough, rigid, high-strength bond in about two hours. The epoxy is highly durable and only requires a one-time application. It also won't crack once dried and it can be applied and cured underwater. Due to this feature, the Epoxy Marine was applied with no issue when it was needed during the testing phase of the submersible robot. The electronics components for the robot were epoxied in place and coated with the hardener. This action waterproofed the submersible components that are exposed to any marine habitat.
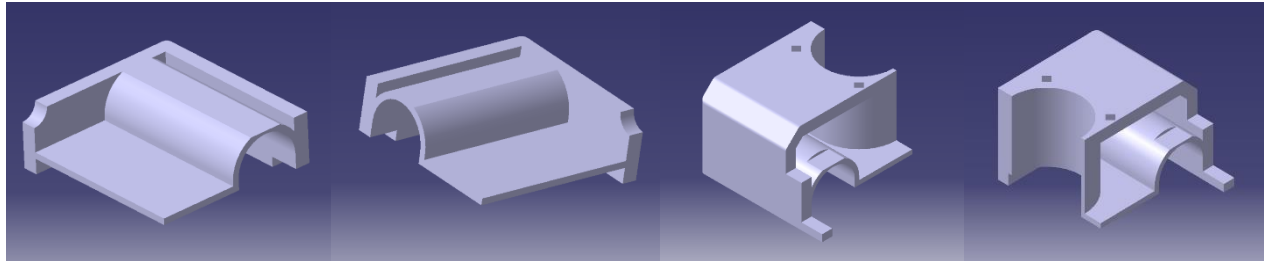


**Figure 8: Base of the Robot Broken up into Four Parts**

The robot's frame was 3D printed into multiple parts to ensure that it fits onto the printer's build plate, seen in Figure 8. The parts were epoxied together, left to set, and flexsealed. The Flexseal was used to cover the submersible, including the epoxied parts, to safeguard the marine life that will be exposed to it.

### 2.3 ELECTRONICS AND SENSORS

Photoresistor (8x)

- Dark Current: .01μA
- Light Current: 4μA - 10μA
- Wired in pairs of two on each side, "inner" and "outer"
- Tuned specifically for the laser's frequency of light

The photoresistors will be used to detect the proximity of the robot to the wall by receiving the reflected light of the lasers. There are four photoresistors on the left and right side of the robot. The pair closest to the laser module is paired together, while the pair furthest from the laser is also paired. If the outside pair of photoresistors loses sight of the laser, this likely means that the robot is close to a wall. This allows us to control the horizontal speed of the robot to prevent collisions. The photoresistors have high resistance when the light is not detected, and resistance lowers as intensity increases. Based on the current passed through the pin, the amount of light can be measured.

Lasers (2x)

- 405 nm blue-violet beam
- Maximum output: 50mW
- Voltage DC: 3.0V – 3.6V

205

The lasers are used for obstacle detection and checking the distance to a wall. There is one laser module pointing to the left and right of the robot. A lens that converts the laser into a straight line will be placed on the diode, drawing a vertical image on the edges of the tanks. The photoresistors pick up on the reflected line and perform certain actions based on what they detect.

405nm frequencies of light were chosen for the ease with which they pass through water and for their lack of interference upon aquatic life. Five volts will be fed to the laser modules by the Raspberry Pi 3 to power them.

Raspberry Pi 3 Model B
- 1 GHz ARM processor
- 40 programmable GPIO pins
- 1 GB of RAM memory
- Micro SD Card capable

The Raspberry Pi was chosen as the controller due to its high specifications and capability to be remotely controlled. The GPIO pins have a high enough refresh rate to power the motor driver and PWM for the thruster. While the Raspberry Pi can use an SD card of any size, only the core operating system (Raspbian), the Python SDK and the programs for running the robot are necessary, which amount to no more than 8 GB of combined data.

Motor Driver

- Local voltage: 5V
- Drive voltage: 5V – 35V
- Maximum power: 25W
- Drive current: 2A
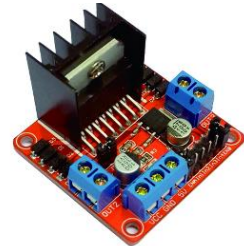
The motor driver is used to drive the stepper motors in the system for horizontal movement. While this motor controller is meant to drive only one stepper motor, our drivetrain only requires the motors to be moving in the same direction. As such, supplying a high enough voltage and splitting the same signal to both stepper motors will suffice, rather than having two drivers. This saves on the number of pins used on the Raspberry Pi, allowing for future upgradability.

Limit Switch (4x)
- 3-terminal microswitch
- Current: 5A
- Voltage: 250V AC

The touch sensors will not be used during the main functions of the robot. Their only purpose is to interrupt the current process if one of them is touched. How the process is interrupted varies depending on consumer preference; if a tank has many animals that prefer staying close to the edges of the tank, this could mean a temporary shutdown to allow the animal to move out of the way. If there are few animals in the tank at all, it is likely that the wall has been contacted without the photoresistors losing the laser. This could simply trigger the robot to continue later.

206

T200 Thruster
- Maximum forward thrust at 12V: 11.2 lbf
- Maximum Current: 25A
- Maximum Power: 350W
- Operating Voltage: 6V - 20V

This robot provides the suction force necessary to keep it against the glass. By removing all the water between the undercarriage of the robot and the glass, a vacuum is created, causing the rest of the water in the tank to push the robot against the tank. Power is controlled on demand depending on the volume of water involved, as larger pressures need the fan to work harder to remove the water. Also, the fan must not be tuned too powerfully, as a complete seal will prevent vertical and horizontal movement.

Stepper Motor (2x)
- 4 pin stepper motor
- 3/16'' shaft
- Voltage: 2.5V
- Current: 2.8A
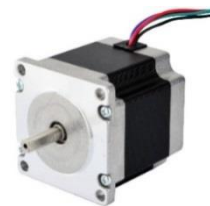
The Stepper Motors are used to drive the omni wheels responsible for horizontal movement. Stepper motors were chosen for their capability in recalling the distance traveled and ease of variable speeds. One stepper motor is responsible for half of the robot's drivetrain, which includes the wheels and the cleaning mechanism. As stepper motors are not waterproof, they are enclosed in a waterproof container, while their shafts are slipped through a waterproof ring seal to drive the motors.

Blue Robotics Basic ESC R3
- 2 pin PWM
- Operating Voltage: 7V - 26V
- Operating Current 30A
- Allows for forward and backward movement
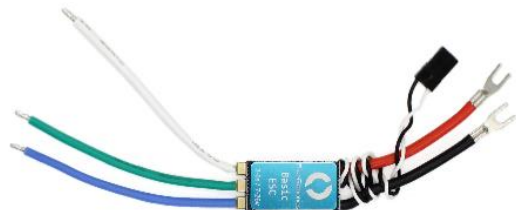
The Electronic Speed Controller is responsible for controlling the thruster's speed, by converting power, ground and a PWM signal into a three-pin output that the thruster uses. While the ESC itself supports 26 V, the thruster only supports 20 V, so this limit cannot be exceeded. To compensate, the PWM can be adjusted to change the current draw from the power supply or stop the thruster entirely. Reducing the PWM to below its cutoff frequency reverses the thruster direction but will likely not be used as this will launch the fan away from the glass.

Relay Module
- Equipped with SRD-VDC-SL-C power relay
- 5V input triggers
- Current: 10A
- Voltage: 30V DC

207
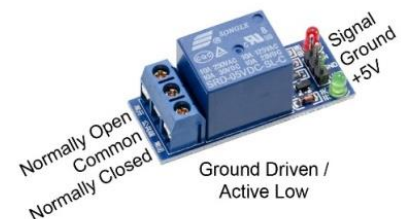
Certain components require a higher voltage than the Raspberry Pi can handle. The Pi can output a max of 5V and that draws current away from the processor, which reduces performance. To compensate, relays can be used to connect certain electronics directly to an external power supply with a far higher voltage capability. The Raspberry Pi instead connects to a separate signal pin, which acts as a switch to pass the larger current through.

### 2.4 PROGRAMMING

As the Raspberry Pi 3 is the main controller on the system, all data is processed there. Using the 40 GPIO pins available, every photoresistor, touch sensor, the stepper controller, and the PWM for the ESC are attached to the Raspberry Pi. To connect power to the T200 Thruster and Stepper motors, which consume too much current for the Pi to output, a relay is used, allowing power to be fed directly from a power supply. To accomplish this, the Python programming language is used, as it has an official open source library for communicating with the GPIO pins. (C++ could have been used, but there is no official library).

The thruster fan is controlled by an Electronic Speed Control unit. This unit takes a high-wattage power/ground input and a PWM signal, translating it into the fan's intended actions. The signal sent through the PWM is a set of pulses sent at a specific frequency. The GPIO library, previously mentioned, along with a library meant for servos, can create this signal by toggling the pin between high and low states. The frequency of the pulses determines the action of the fan, as indicated by Figure 8.
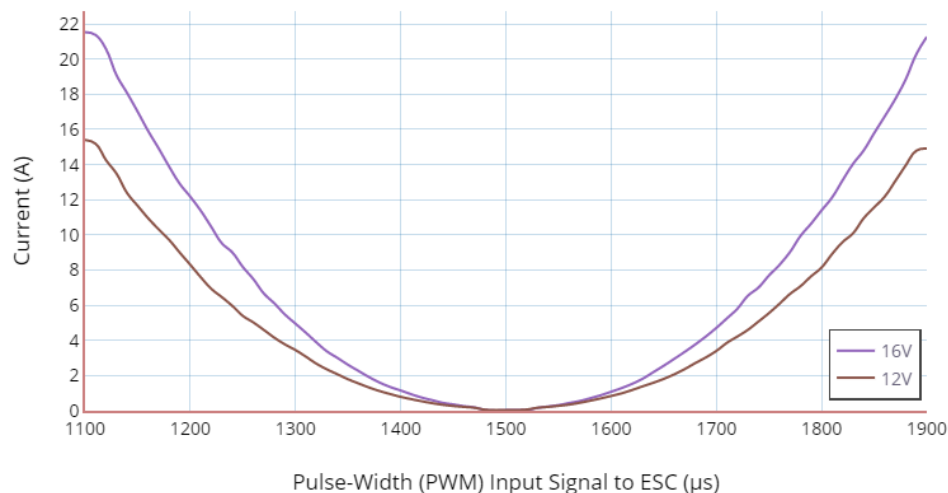


**Figure 9: Chart for converting the frequency of PWM to the output current of the fan. 1500 us per signal is the dead zone for the fan, meaning no action is taken. >1500 moves the fan forward, <1500 backward. [5]**

The entire program is split into three components: Initialization, Cleaning Cycle, and Emergency Scenario. The Initialization is naturally the first function to run, which handles the user's cleaning request and calibration actions. The Cleaning Cycle runs multiple times depending on the size of the tank, changing direction after each cycle. The Emergency Scenario function only runs in the event of a touch sensor being pushed, and changes depend on the consumer's pre-programmed instructions.

208

By connecting the photoresistors to the 3.3 V pin and a dedicated input pin on the raspberry pi, the Pi can detect when a laser is seen by the photoresistor. Shining a laser reduces the resistance, as previously stated, which will allow more current through the mini-circuit. Once the input pin's voltage exceeds a certain threshold, it changes state from low to high power. At high power, we can assume that the robot is detecting as much light as possible, so this is the "always on" state (as the laser should be reflected unless the robot is near the wall). Should the pin receive a low power state, it can be assumed the laser has left the view of the photoresistor.
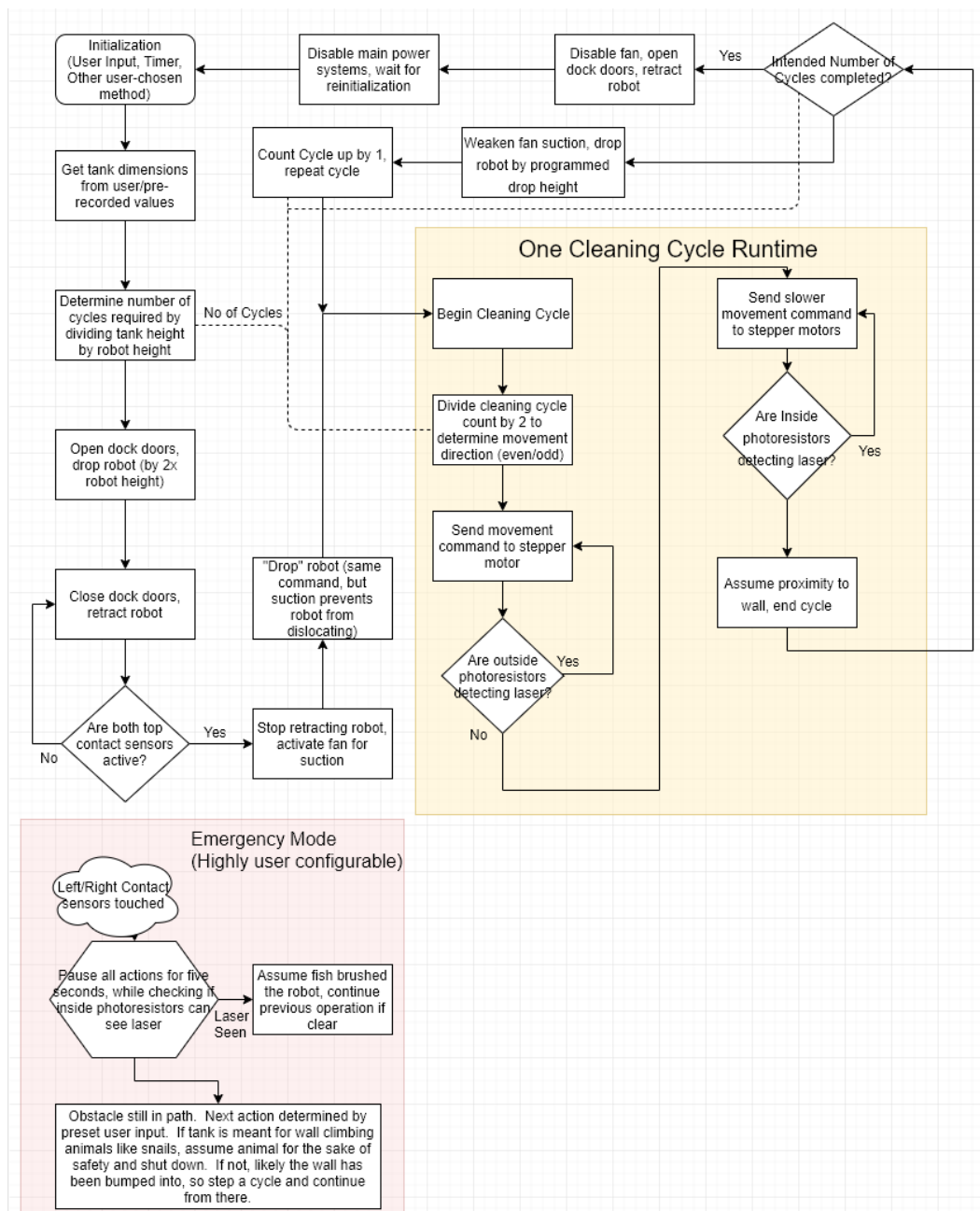
**Figure 10: Flowchart for the code run on the Raspberry Pi. The Emergency Mode is an interrupt process triggered by the contact sensor**

209

The stepper motors are programmed through an alternating sequence system, using the GPIO library once again. The same code is repeated endlessly until the lasers trip or emergency is called.

```python
1    #!/usr/bin/python
2    # Import required libraries
3    import sys
4    import time
5    import RPi.GPIO as GPIO
6
7    # Use BCM GPIO references
8    # instead of physical pin numbers
9    GPIO.setmode(GPIO.BCM)
10
11   # Define GPIO signals to use
12   # Physical pins 11,15,16,18
13   # GPIO17,GPIO22,GPIO23,GPIO24
14   StepPins = [17,22,23,24]
15
16   # Set all pins as output
17   for pin in StepPins:
18     print "Setup pins"
19     GPIO.setup(pin,GPIO.OUT)
20     GPIO.output(pin, False)
21
22   # Define advanced sequence
23   # as shown in manufacturers datasheet
24   Seq = [[1,0,0,1],
25          [1,0,0,0],
26          [1,1,0,0],
27          [0,1,0,0],
28          [0,1,1,0],
29          [0,0,1,0],
30          [0,0,1,1],
31          [0,0,0,1]]
32
33   StepCount = len(Seq)
34   StepDir = 1 # Set to 1 or 2 for clockwise
35            # Set to -1 or -2 for anti-clockwise
36
37   # Read wait time from command line
38   if len(sys.argv)>1:
39     WaitTime = int(sys.argv[1])/float(1000)
40   else:
41     WaitTime = 10/float(1000)
42
43   # Initialise variables
44   StepCounter = 0
45
46   # Start main loop
47   while True:
48
49     print StepCounter,
50     print Seq[StepCounter]
51
52     for pin in range(0,4):
53       xpin=StepPins[pin]# Get GPIO
54       if Seq[StepCounter][pin]!=0:
55         print " Enable GPIO %i" %(xpin)
56         GPIO.output(xpin, True)
57       else:
58         GPIO.output(xpin, False)
59
60     StepCounter += StepDir
61
62     # If we reach the end of the sequence
63     # start again
64     if (StepCounter>=StepCount):
65       StepCounter = 0
66     if (StepCounter<0):
67       StepCounter = StepCount+StepDir
68
69     # Wait before moving on
70     time.sleep(WaitTime)
```

**Figure 11: Code used to connect the Raspberry Pi through the Stepper Controller to the Stepper Motors. (*Note: Subject to Change*)**

## 3. COMMERCIAL USABILITY

This autonomous aquatic tank cleaner is designed to scrub algae and other fish byproduct from the sides of commercial marine tanks. Using a Raspberry Pi Model B, a handheld controller is used to enter the dimensions of the tank being cleaned. Its homing dock is braced to the corner of the tank with a pulley system and a steel tether, which is attached to the submersible cleaner. When set to run, the cleaner is lowered down the tank to ensure that it is straight. The T200 thruster creates suction to the walls and scrubber bars, located on the base of the robot. The stepper motors are then turned on to start the cleaning process. Its waterproofed electronic components allow the entire body of the cleaner to become a ballast system. The robot is aided with Omni Wheels and moves up, down, and side to side without an issue.

A submersible with such capabilities is in high demand within the marine tank industry. Its functionality lowers cleaning times and increases the quality of cleanliness it produces. With the submersible on hand, less effort and equipment are needed, thus saving money on the cleaning process. Fewer hires are needed to clean the tanks and the environment also becomes safer, because there is no longer the necessity for divers and other employees to enter the tank for a manual scrub down.

210

## 4. CONCLUSION

After extensive research and examination, we determined that the cleaning of subaquatic systems, namely aquariums, is both inefficient and ineffectual. Thus, the proposed project aims to establish a more effective system for cleaning the subaquatic viewing ports of aquariums and similar surfaces. Our product is an autonomous solution for the outdated methods of cleaning aquarium fish tanks. In addition, this product can operate with minimal human interaction, and it is amenable within a range of tanks,

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# Mechatronics in the Advancement of Automated Climate Control

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## ABSTRACT

This research project involves the development of an innovative automated climate control device. The automated climate control device consists of a frame with vertical plexiglass panels, which would be placed in an open window of a room. The panels are programmed to open and close automatically to allow air flow through the window and to maintain a desired temperature in the room. This is done by using an indoor and outdoor temperature sensor to compare temperature values and adjust the opening of the panels. This device will be inexpensive, reliable, and simple to produce. These features are essential in the engineering of the device since it offers a more marketable product to the consumer. Consumers will greatly benefit from the automated device as it will help save energy on HVAC while providing comfort at the same time. Currently there are no known devices that control the opening and closing of a window based on outdoor to indoor temperature differences. The most similar product found, opens and closes a window based on the time of day and on user input.

## 1. INTRODUCTION

Heating, ventilation, and air conditioning (HVAC) is the technology of indoor and vehicular environmental comfort. The goal of this paper is to provide high indoor air quality while allowing users to modify the temperature in the room. HVAC systems are an important part of both residential and commercial structures such as public housing, hotels, and single-family homes.

It is important to understand the aspects of an HVAC system so that the device can produce comparable results. One of the most popular ways to distribute heat using an HVAC system is with a heat pump. This pump can extract heat through various sources such as the exhaust air from a building or the ground. Another popular way to heat is with the use of space heaters and boilers, especially in larger buildings that house multiple apartment units. However, these can be

212

very dangerous due to the emission of carbon monoxide, a tasteless and odorless gas with serious and possibly fatal health effects.

Most HVAC systems use forced ventilation to control indoor air quality. However, in certain climates, more energy is required to remove excess moisture from ventilation air, raising utility bills. This device will use natural ventilation. The opening and closing of this device uses very little energy, and since it is attached to a window, the room is ventilated with the outside air, a key factor in limiting the spread of airborne illnesses [4].

This device will investigate the possibility of maximally diminishing energy loss through windows with inside and outside temperature difference.

## 2. CONSUMER NEED

In residential housing, where HVAC systems are sometimes non-existent or need improvement, heating and cooling may be inefficient and expensive. A major problem is the loss of system efficiency due to inconsistent airflow and uneven heating and cooling throughout the building. These problems create a need for an automated mechanism that can regulate the change in temperature air flow in a room, whether the user is at home or away. In homes with no HVAC systems, ventilation is problematic. According to the EPA, a lack of air movement in a home can cause a buildup of toxic pollutants in the air by a factor of ten [5]. Another study done by UCLA, concluded that in some climate areas, opening and closing windows at the right time can significantly save on heating and cooling costs.

**Table 1: Heat index of an apartment during various times of day [1]**



213
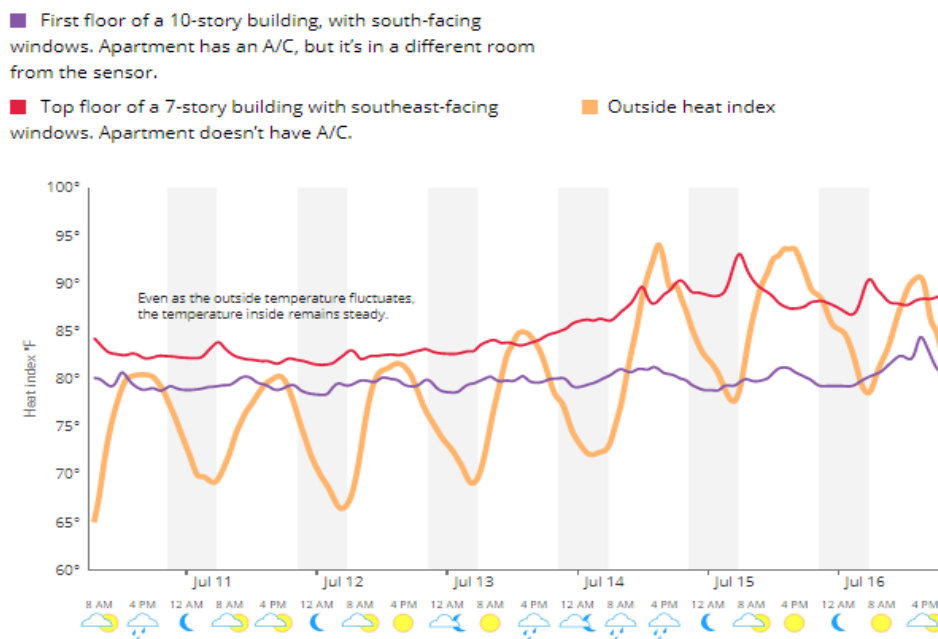
## 3. MATERIALS



**Fig.1:**
**Lumex LCD LCM**



**Fig.2:**
**PIC18F4580 microcontroller**



**Fig.3:**
**Parallax servo model**



**Fig. 4:**
**Multi-Programmer Board**
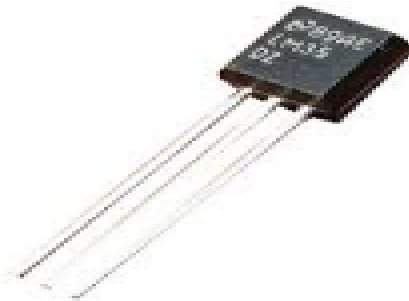


**Fig. 5:**
**LM35 temperature Sensors**



**Fig. 6:**
**HM-05 Bluetooth Module**

## 4. DESIGN

The dimensions of the frame were made to be 20 in. x 13.6 in., so the frame could fit most window sizes. The frame allows room for the electronic components such as the microcontroller, sensors, and servo motor, to be stored and protected from outside interference, while allowing for the LCD display and buttons to protrude from underneath. The plexiglass panels are attached to small cases on the top and bottom of each panel. The cases are fixed to the frame at one end and attached to a rod on another end. This rod is attached to the servo motor. As the servo motor rotates, the motion is translated from a rotational displacement to a linear one, in other words the rod will move left or right depending on whether the servo rotates clockwise or counterclockwise, thus rotating the plexiglass panels. The servo is connected to the microcontroller, which determines the degree and direction in which the servo will rotate, based on 2 temperature sensors, one placed indoors and one outdoors. The device is powered by batteries, which is a low cost and energy solution compared to HVAC systems.

214
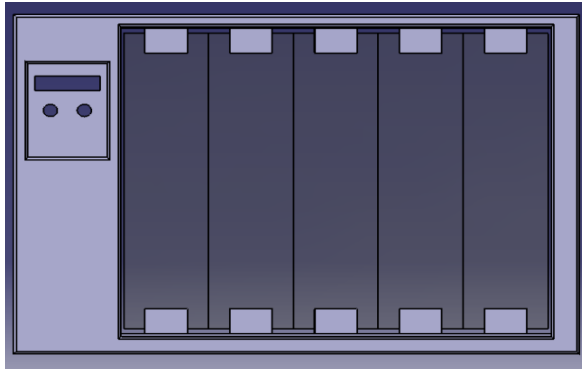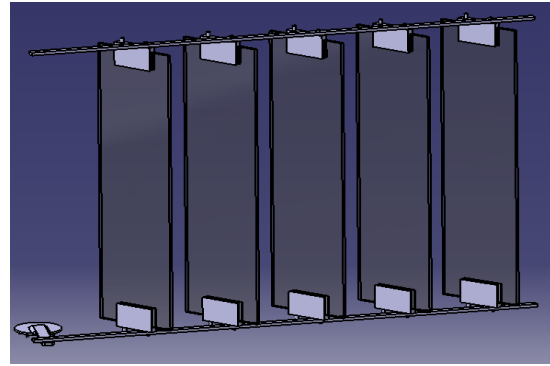
Fig. 7(a)                                          Fig. 7(b)

**Fig. 7: (a) 3D assembly of the device, shown in front view. (b) The assembly shown in fig. 8b displays the moving parts of the device, which allow for the panels to open or close**



**Fig. 8: 3D assembly of the device with opened panels.**
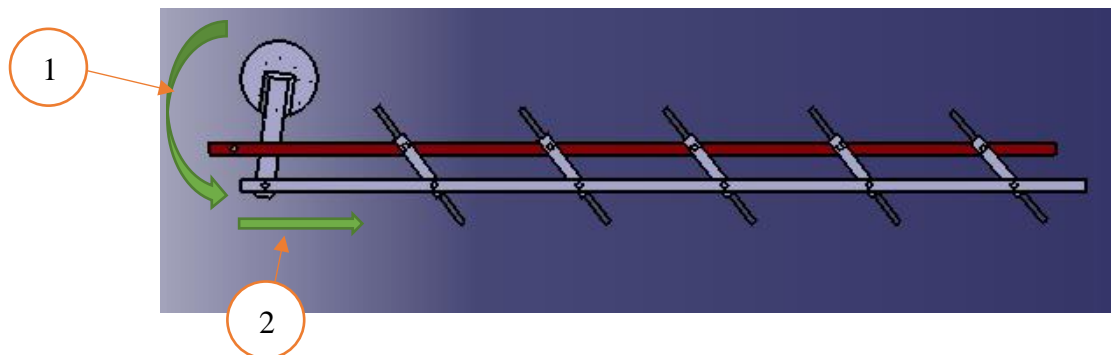


**Fig. 9: Top view of the mechanism which allows movement. The red rod represents a fixed structure in place of the frame. As the servo arm (1) rotates counter clockwise, the rod (2) moves to the right. The connections between the servo arm, the rod, and the plexiglass cases are all hinge joints.**

215

## 5. THEORETICAL CALCULATIONS

The pressure of the air can be calculated by the following formula:

$$p \approx p_0^{\left(-\frac{g*M*h}{R_0*T_0}\right)} \tag{1}$$

$P_{out}$=97931 Pa; $P_{in}$=101206 Pa; $\Delta P$=3275 Pa. Where the constant parameters are as described below:

**Table 2: Values of air parameters**

| Parameter | Description | Value |
|---|---|---|
| $p_0$ | sea level standard atmospheric pressure | 101325 Pa |
| $L$ | temperature lapse rate, = $g/c_p$ for dry air | 0.0065 K/m |
| $c_p$ | constant pressure specific heat | ~ 1007 J/(kg•K) |
| $T_0$ | sea level standard temperature | 288.15 K |
| $G$ | Earth-surface gravitational acceleration | 9.80665 m/s$^2$ |
| $M$ | molar mass of dry air | 0.0289644 kg/mol |
| $R_0$ | Universal gas constant | 8.31447 J/(mol•K) |
| H | Sea level altitude | 10 |

The problem of mixing entering air and internal air and equilibrium temperature of the mixture can be expressed in terms of Gibbs Free Energy: $\Delta_{mix}G = n_A R T_A \ln(P_A^*) + n_B R T_B \ln(P_B^*)$, where $n_A$=464.6 mol, $n_B$=0.845 mol - are molar quantities of mixing masses A and B in constant volme V=11 m$^3$, with air flow rate $\dot{m}$=0.045 kg/s, $T_A$=300 K, $T_B$=273 K - are their temperatures and P* is the relation of pressure of each gas mass to the sum of pressures of both gases $P_A^*$=0.51, $P_B^*$=0.49.

For short intervals of time (less than 30 minutes) the dissipation of heat through walls, window surface, floor and ceiling is negligible and the simplified model of a system with small time intervals can be expressed as:

$$\Delta_{mix}G = n_A R T_A \ln(P_A^*) + n_B R T_B \ln(P_B^*) - n_A R T_{in} \ln(P_B^*); \tag{2}$$

From first law of thermodynamics for air:

$$\Delta_{mix}G = n_A R T_A \ln(P_A^*) + n_B R T_B \ln(P_B^*) - n_A R T_B \ln(P_B^*); \tag{3}$$

Substituting values we obtain $\Delta_{mix}G$:

$\Delta_{mix}G$=779848.87 J; (4)

To obtain $T_{in}$, divide $\Delta_{mix}G$ by $n_B R \ln(P_B^*)$:

$T_{in}$=299.98 K. (5)

For optimal control of temperature with opening and closing of air flow, the sensor feedback is utilized:
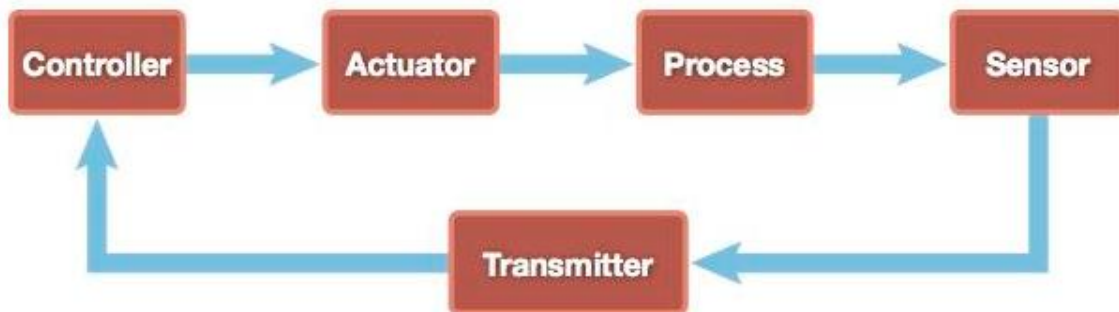


**Figure 9: Feedback control of the system**

Where Controller is a MCU (PIC18F4580), Actuator is a servo operated louver, Process is heat exchange in a room, Sensor is temperature sensor (TMP36), and Transmitter is a Bluetooth Module (HC-05).

**Table 3: Description of function block diagram of the microcontroller program**

| **Function block diagram of the microcontroller program.** |
| :---: |
| **RD1: Servo Control** |
| RD2: t++ |
| RD3: t-- |
| RA0/RA1: inside/outside temperature |
| Port B: LCD |
| RD7: LCD en |
| RD6: LCD rw |
| RD5: LCD rs |
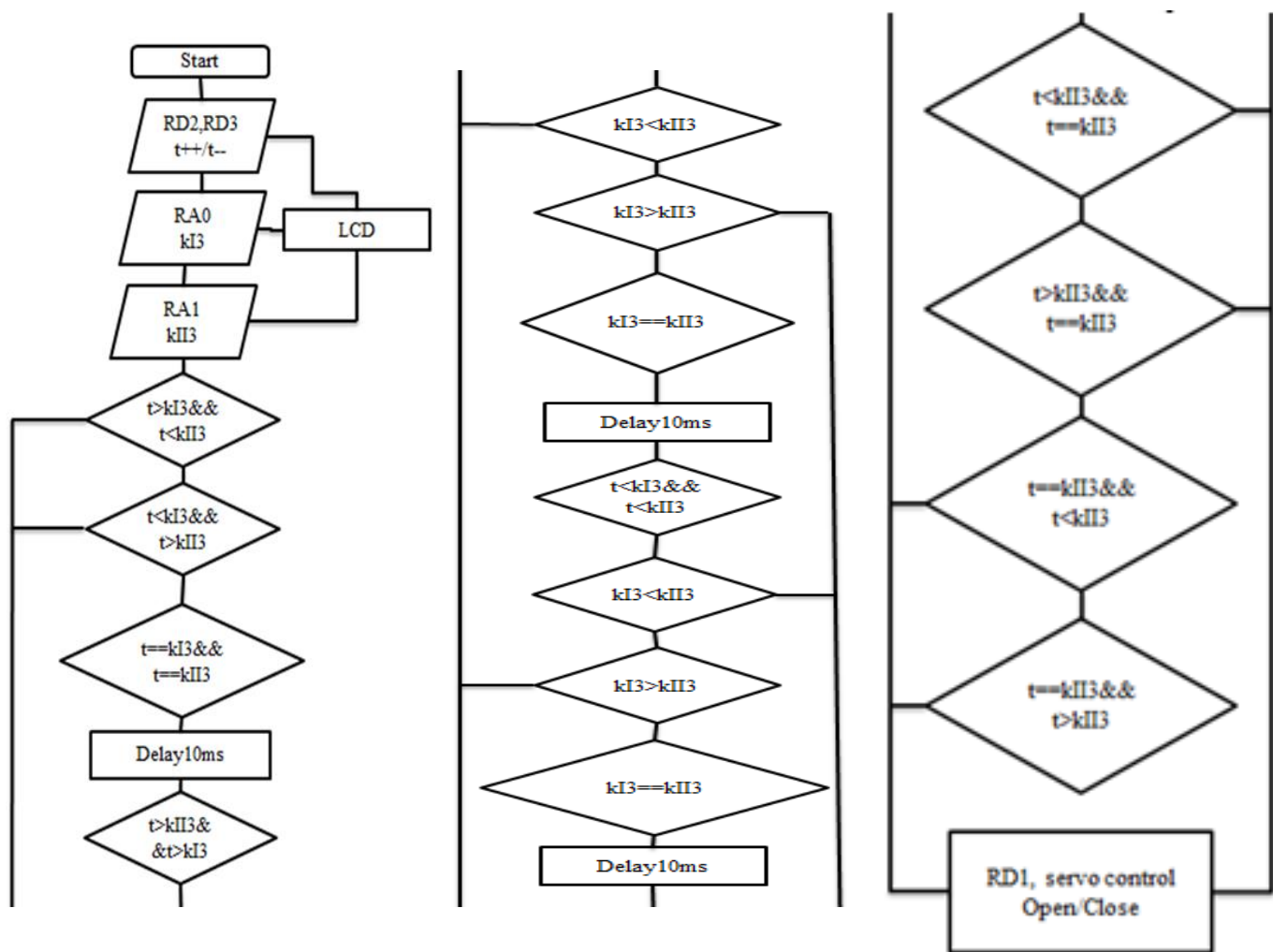
**Fig. 10: Function block diagram of the microcontroller program**

The program below uses the ADC on the PIC18F4580 chip to convert the measured analog signal from the temperature sensor, TM35, into the digital signal and displays the room temperature on the LCD module. Then it compares the temperature with the set value and operates the servo based on that condition.

```c
#pragma config OSC = IRCIO67
#pragma config BOREN = OFF
#pragma config WDT = OFF
#pragma config LVP = OFF
#pragma config PBADEN = OFF


#include <P18F4580.h>
#include "lcd_fun.c"

  unsigned char str1[]="Room Temperature", ASCII_temp[9];
  void digital2ascii(unsigned int digit_value)
  { unsigned long temp;
    unsigned int h_digit,h_remainder,t_digit,t_remainder,u_digit,ts_digit;// int

  temp = (unsigned long)digit_value;  // 5000* e.g. T=25C ; here T=(25+50)*100=750C
//     temp = temp*5000/1023-500;
  h_digit        =temp/1000;       //get hundred
  h_remainder    = temp%1000;
  t_digit        = h_remainder/100;
  t_remainder    = h_remainder%100;
  u_digit        = t_remainder/10;
  ts_digit       = t_remainder%10;

  ASCII_temp[0]= h_digit+0x30;
  if(ASCII_temp[0]==0x30) ASCII_temp[0]=0x4e;
  ASCII_temp[1]=t_digit+0x30;
  ASCII_temp[2]=u_digit+0x30;
  ASCII_temp[3]= '.';
  ASCII_temp[4]= ts_digit+0x30;
  ASCII_temp[5]= ' ';
  ASCII_temp[6]= 0xdf; //degree sign
  ASCII_temp[7]= 'C';
  ASCII_temp[8]= 0x00; // the null character
  send_str(ASCII_temp); //Send temperature to LCD
  }
```

219

```
    void delay_10us(unsigned int itime)
 {
    unsigned int i;
    for(i=0;i<itime;i++);
 }


void notes (unsigned float freq, unsigned float duration)
{
    unsigned long counts, j;
    unsigned int half_period;
    counts = (unsigned long) freq;
    half_period=(unsigned long) 2150-duration;

    for (j=0; j<counts; j++)
    {
        PORTDbits.RD1 = 1;
        delay_10us(duration);
        PORTDbits.RD1 = 0;
        delay_10us(half_period);
    }
}
    void main(void)
   { unsigned int k;  unsigned int AD_temp;unsigned long k1;unsigned int k2,k3;
OSCTUNEbits.PLLEN=1;
OSCCON=0b01111100;
TRISDbits.TRISD1=0;
TRISAbits.TRISA0=1;  //RA0: input
ADCON0=0x01; ADCON1=0x0E; ADCON2=0b10110110;

    CMCON =0x07;
    TRISDbits.TRISD5=0;  //RB3: Output=>LCD rs
    TRISDbits.TRISD6=0;  //RB1: Output=>LCD rw
    TRISDbits.TRISD7=0;  //RB2: Output=>LCD en
    TRISB=0;             //PortD: Output
    init_lcd();          //Initial LCD Module
    lcdcmd(0x80);        //Write on the first line
    send_str(str1);      //Send "Room Temperature"

    while(1)
          {
            MSDelay(1);
                ADCON0bits.GO_DONE=1;    //Get the ADC measurement
                while(ADCON0bits.GO_DONE==1);
                AD_temp = (unsigned int) ADRESH <<8;
                AD_temp = AD_temp | (unsigned int)ADRESL;
    k1=AD_temp;
    k2=k1*5000/1023-500;         k3=k2/10;
    // lcdcmd(0xC0);   //Display the room temperature
    // digital2ascii(AD_temp);
    lcdcmd(0xc8);
    digital2ascii(k2);
            MSDelay(250);
    if (k3>=33)
        {notes(50, 105);MSDelay(300);}
    else if (k3<33)
        {notes(200, 35);MSDelay(300);}
              }
          }
```

**Fig. 13: Program for the microcontroller to receive and display sensor input, as well as control motor output**

## 6.  CONCLUSION

An innovative automated climate control device has been developed in this project. It is known that HVAC systems are a crucial part of any residential structure. So, when buildings do not offer HVAC systems, consumers may find a cost-effective way to keep air flowing through a room while maintaining a comfortable temperature. In this project, the method used to control the air flow in and out of a room saves energy and provides for more comfort for the consumers. The device is a unique product on the market with an affordable price. It is comparatively simple to manufacture and it incorporates the use of novice microcontrollers to simplify the task. In future iterations, this device can also be adapted for use on vents. The automatic climate control device has the potential to become a competitive product on the market.

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# Experimental Study of NACA Joukowski-0015 Airfoil with Built-in Moving Surface Mechanism

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**ABSTRACT**

Generation of lift is the result of the flow characteristics of the object; the most important aspect that contributes to high lift force is the shape of the object. Therefore, an airfoil is a highly optimized shape for lift generation which produces a small drag force. In this project an investigation of a standard airfoil, NACA-Joukowski-0015, is being equipped with a mechanical system to provide motion to its surface at a portion of the airfoil located at the leading edge and occupying 18% of the total chord length. This study is meant to understand the effect of moving surface on the lift generation and drag force. The present study looks into the data produced experimentally and via CFD simulation. The experiment is conducted in an EWT-Aerolab wind tunnel facility in the thermo-fluid laboratory at Vaughn College. The simulation is executed in COMSOL Multi-physics CFD module. The moving mechanism is designed, built and assembled in house. To better understand the effect of the moving surface, a comparison is made to standard NACA-Joukowski-0015 airfoil built with the same dimensions to be tested under the same conditions. In the manufacturing process of the system component, models from multiple 3D printers are used to produce the optimal design. Moreover, due to the large size needed for the airfoil section, the airfoil is designed in nine small sections that are assembled to produce the desired size. The moving surface has shown a high increase in turbulence vibration as can be observed through collected data and images from a high-speed camera. The simulation provided insight into the behavior of the flow, under different speeds for both the flight and the surface.

## 1. INTRODUCTION

The flow field around an object is the main source of the aerodynamic load generated. According to the Kutta-Joukowski theorem "The lift per unit span is directly proportional to circulation [1].



$$\dot{L} = \rho_\infty V_\infty \Gamma$$
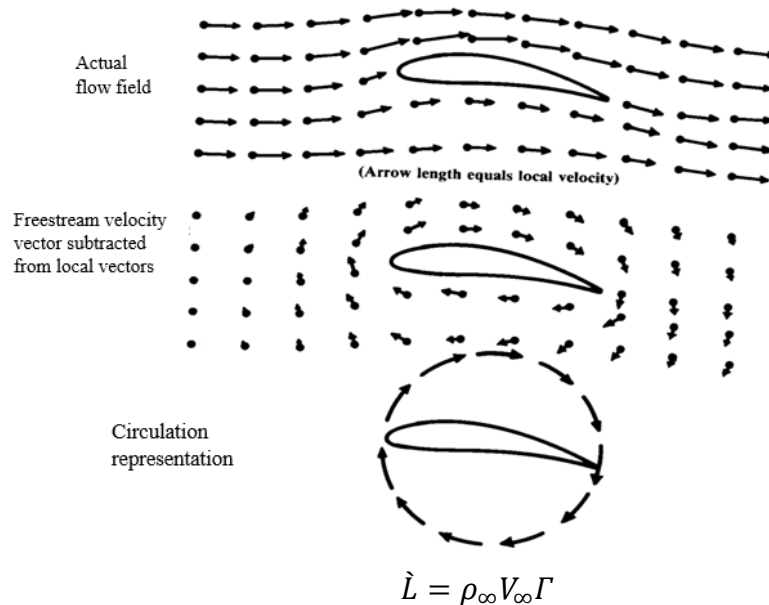
**Figure 1: Lift generated by circulation Γ**

Hence, the increase of circulation about the airfoil will result in the increase of lift force [2] (figure1). However, the motion of the surface may also result in the decrease of the total circulation and will depend on the new flow characteristics over the body. In this study, the moving surface mechanism is built in a way to provide flexibility in the change of the speed as well as in the direction of the surface.

This project objective is to design and build an experimental setup for moving an NACA Joukowski 0015 airfoil with a moving surface. This experimental setup will be tested to investigate the flow around an airfoil. In this project, a wind tunnel will be used as a platform to measure the normal and axial forces and calculate the lift and drag coefficients.

The results of lift and drag force acting on the airfoil will be analyzed and compared with the identical airfoil based on theoretical and experimental literature, in order to obtain a better understanding of flow characteristics. The initial focus of this work is on the design and the build of the moving mechanism, also referred to as the conveyer belt; the selection of NACA Joukowski0015 Airfoil setup will allow this team to study and compare the differences between the standard and the novel airfoil with a moving surface.

This work is combined with simulation analysis using CFD module in COMSOL Multiphysics using a variety of flow condition cases.

## 2. DESIGN AND ASSEMBLE

The design involves two main parts; the first is the standard JOUKOVSKY f=0% t=15%, and the second is the similar airfoil equipped with a moving wall mechanism.

### 2.1 DESIGN THE STANDARD JOUKOWSKI AIRFOIL

The first design is the standard NACA airfoil Joukowski f=0% t=15%. This airfoil was chosen because of its symmetrical geometry, in addition to its large thickness of 15%. This is one of the airfoil models with the largest thickness of all the symmetric airfoil; therefore, it is capable of containing the moving conveyor belt mechanism that produces surface motion.
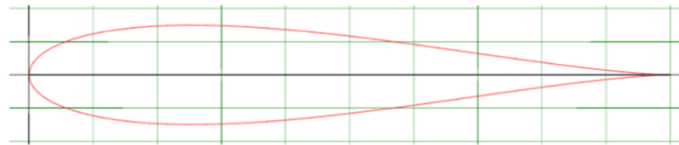


**Figure 2: 2D sketch of NACA Joukowski 0015 generated by MATLAB code [3]**

To create a 3D CAD design from a 2D sketch based on NACA details and Data file, seen in figure 2, the 3D CAD design was created in SolidWorks, seen in figure 3, and MATLAB code was used to obtain more coordinate points, by interpolation, to produce smooth airfoil surface from a high-resolution curve. In this case, a 500-point curve is generated for both the upper and the lower surface by the MATLAB code. Then the coordinate points were imported to SolidWorks to produce the airfoil section. The airfoil dimensions are also scaled to be suitable for the wind tunnel's testing area dimensions, which are 30X30 cm$^2$. In addition, a small hollow tube holder was designed at the trailing edge of the airfoil to be mounted on the wind tunnel's force balance system. 3D printing was used to build the wing section. However, due to the large size of the wing section, the airfoil had to be divided into nine parts in order to use the 3D printers. Moreover, a key design and a sliding mechanism are created to assemble the airfoil. The first three parts are the sliding mechanisms which make it easy to change between airfoils, which are 20% of the chord line from the leading edge. The 18% was chosen to reach the maximum thickness with the conceptual airfoil. In addition, the remainders of the nine pieces are kept the same to use for both airfoils.
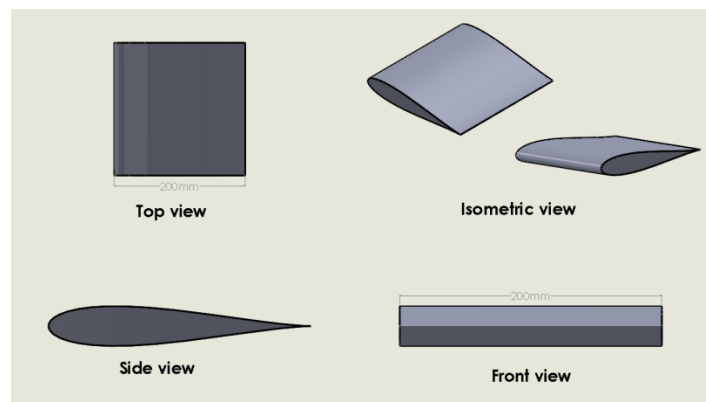


**Figure 3: 3D cad design in SOLIDWORKS software**

## 2.2 DESIGN THE MOVING CONVEYOR BELT MECHANISM

The moving conveyor belt mechanism is built to replace the leading-edge section of the airfoil as shown in figure 4. The idea is to have a driving shaft, idlers, conveyor belt, and a filler as a moving conveyor belt mechanism; therefore, the design consists of one driver, seven idlers, one belt and filler. The multiple components, particularly the seven idlers, are used to preserve the curvature of the airfoil profile. However, this design was discounted for use, after proving too complicated in terms of assembly and operation.
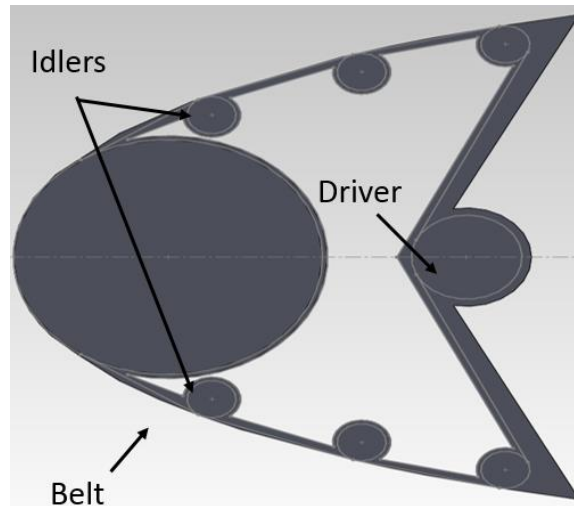


**Figure 4: The surface motion produced by conveyor belt mechanism "initial design"**
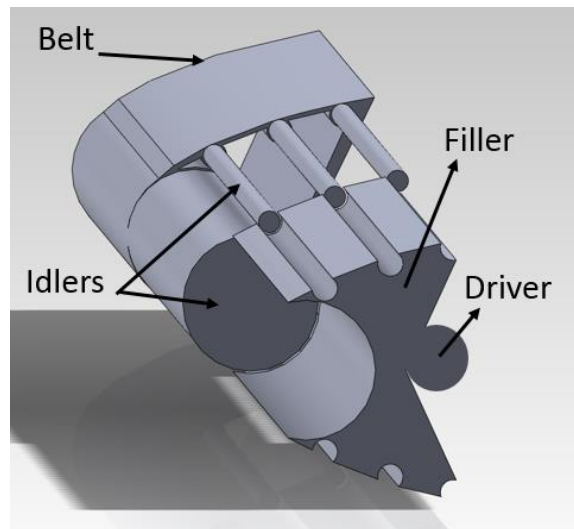


**Figure 5: 3D model of the final design of conveyer belt mechanism**

## 2.3. FINAL DESIGN OF CONVEYOR BELT MECHANISM SECTION

The final mechanism design replaced the airfoil leading edge with a moving conveyor belt mechanism, and the design consists of one driver, two idlers, one belt and filler to preserve the airfoil standard profile.
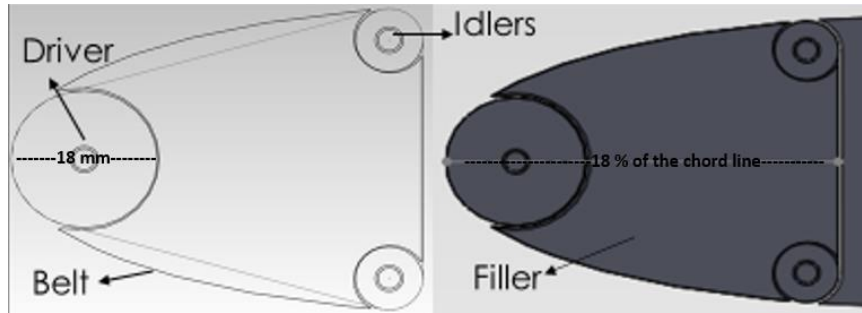
**Figure 6: the airfoil leading edge mechanism**

A smaller cylinder was added to the tip idlers and the driver shaft to easily mount on the plate and bearings to the cylinders; however, the driver was fixed with only one bearing on one side, and on the other side, it was attached to the shaft hub, which is fixed to the motor's shaft using a fastener. This bearing allows the cylinders to rotate freely in the wind tunnels' testing area, while the filler and the rest of the airfoil is fixed to reduce the vibrations of the system. Figures 7 and 8 show the final configuration of the assembly.
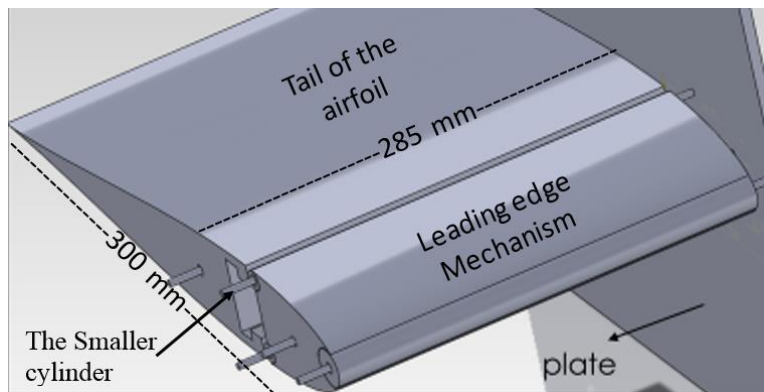


**Figure 7:  The Final Moving Conveyor Belt Mechanism Airfoil**

Moreover, the cylinders and the filler are divided into three parts, each due to the 3D printer size limits previously discussed. Therefore, the cylinders and the filler are designed with a key way and mounting key.



**Figure 8: Cylinders and Filler with key design and a key way**

226

The design that involves the 3D printed cylinders was eventually discarded because it failed frequently as the cylinders were too slender to sustain the torque and the aerodynamic loading during operation. Therefore, wood cylinders were chosen to replace the 3D printed cylinders. At one end, the wind tunnel, a plate made of transparent Plexiglas, was designed to be a side mount for mechanism components. Finally, the new configuration was tested in the wind tunnel and approved for its sturdiness and simplicity.

In summary, the mechanism of the modified symmetric Joukowski Airfoil is modified on the leading edge of the airfoil section, while, as shown in Figure 10, leaving the remainder of the airfoil similar to the standard design. The modification of the standard airfoil involved cutting off 18 % from the leading edge and replacing it with a conveyor belt attached to three cylinders. All assembled in one complete mechanism, we added a filler part with the same shape of the cut piece from the original airfoil.
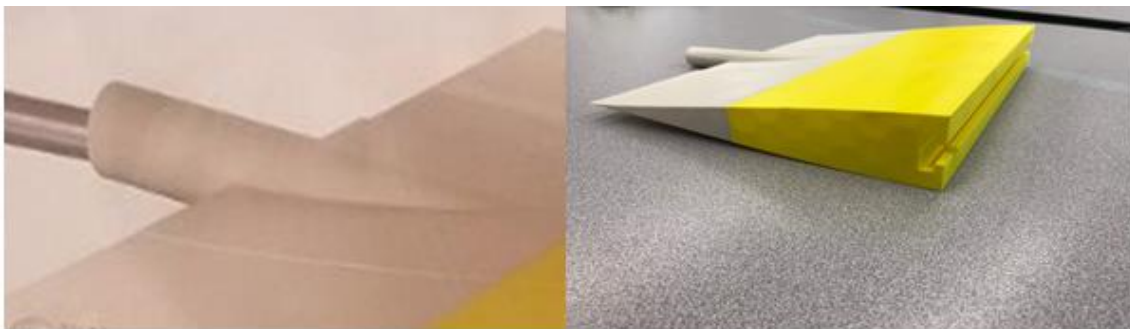


Figure 9: Holder balance shaft          Figure 10: The tail sliding mechanism
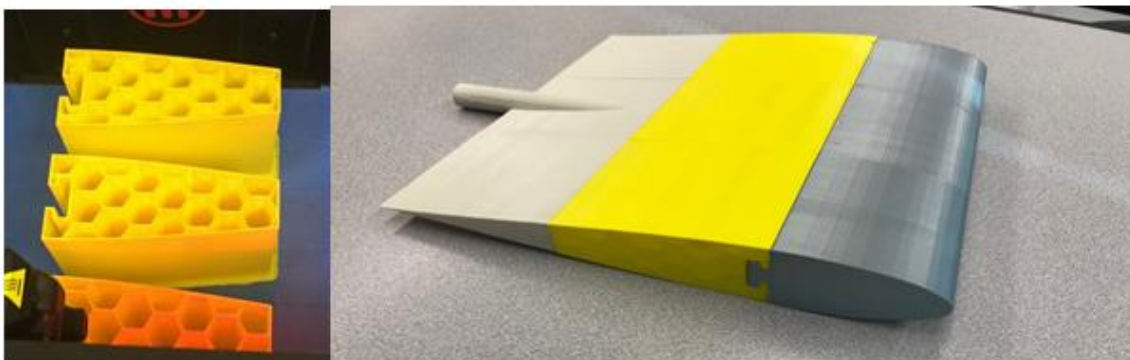


Figure 11: the printed of the original airfoil Design
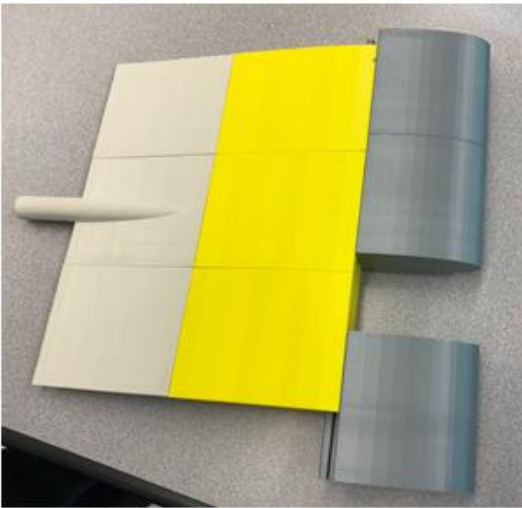
3. ASSEMBLY

3.1 ASSEMBLE THE ORIGINAL AIRFOIL

Assembly the original airfoil, which can be seen in figures 12 to 15, consists of two parts, first is to assemble the tail parts of the airfoil together, then the second part is to assemble the sliding leading edge parts of the airfoil together.
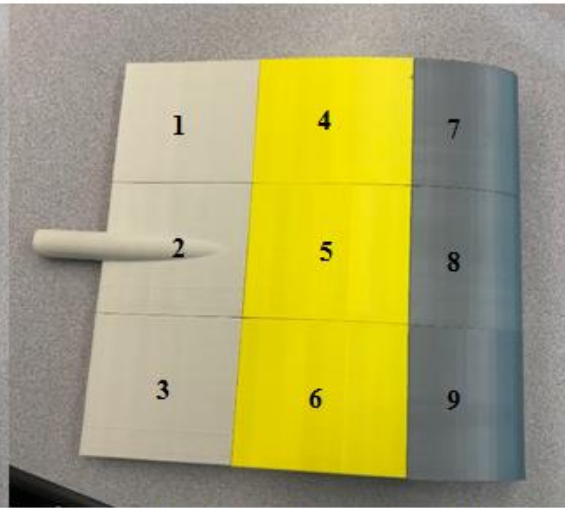
227

Figure 12: the fixed part, the tail



Figure 13: the leading edge of the airfoil



Figure 14: Sliding mechanism



Figure 15: The airfoil after assembling

Assembling the mechanism consists of three parts, the first part is to assemble the sections of the airfoil together, then the second part is to assemble the mechanism into the plate outside the wind tunnel testing area. The final part is to assemble the mechanism with the plates inside the wind tunnel testing area.

First, we assembled and fixed the cylinder's and the filler parts together with the key design and key way, by puttering the key design in the key way and making sure that all lined up to obtain a perfect cylinder. Moreover, through the use of a drill, a centered hole was created in the wooden cylinders to fix the small parts that were added at the ends of the cylinders to mount on the bearings. The final task was to assemble the driver to the motor by using a shaft hub to connect the flat end of the driver cylinder to the slippery shaft of the motor, which is fixed to the motor's shaft using a screw.

Additionally, the bearings are fixed in the plate by mounting them in 3D printed flat parts, and then the small flat parts are mounted and fixed into the plate. However, the plates need to be transparent to allow for visualization. The plate was cut perfectly, since the wind tunnel testing area and the holes for the bearing are measured for an exact 0° angle of attack and to line up with the rest of the airfoil without blocking or changing the flow direction and the airfoil original shape. Finally, assemblage and mounting of the parts to the plates must be executed. Some

228

parts, however, required a small piece to be perfectly fixed in the right place, so a small 3D printer design was made and printed to assemble the parts more easily.



Figure 16: Assembly of the leading-edge section- Modified airfoil

### 3.2. MOUNTING THE AIRFOIL MECHANISM FOR WIND TUNNEL TESTING

The last step is the assembly of the mechanism with the plates inside the wind tunnel testing area, which can only be reached from a small window from the top of the wind tunnel testing area, and this process must be carried out in multiple steps tin order to align the motor shaft perfectly with the tail of the airfoil.



Figure 17 mount the mechanism into the plates

Additionally, the controller [4] and other connections are assembled by first connecting the motor [5] to the controller with the wires and then connecting the controller to the voltage supply. Second, the computer must be mounted to open the monitoring velocity of the motor. Third, the high-speed camera [6] must be mounted pointing towards the testing area of the wind tunnel [7]. Fourth, the laser on top of the wind tunnel must be mounted and then the mirror in

229

front of the laser is mounted to reflect the laser sheet to the airfoil. Finally, the smoke machine is mounted in front of the wind tunnel in order to allow smoke to flow in the wind tunnel airflow direction.
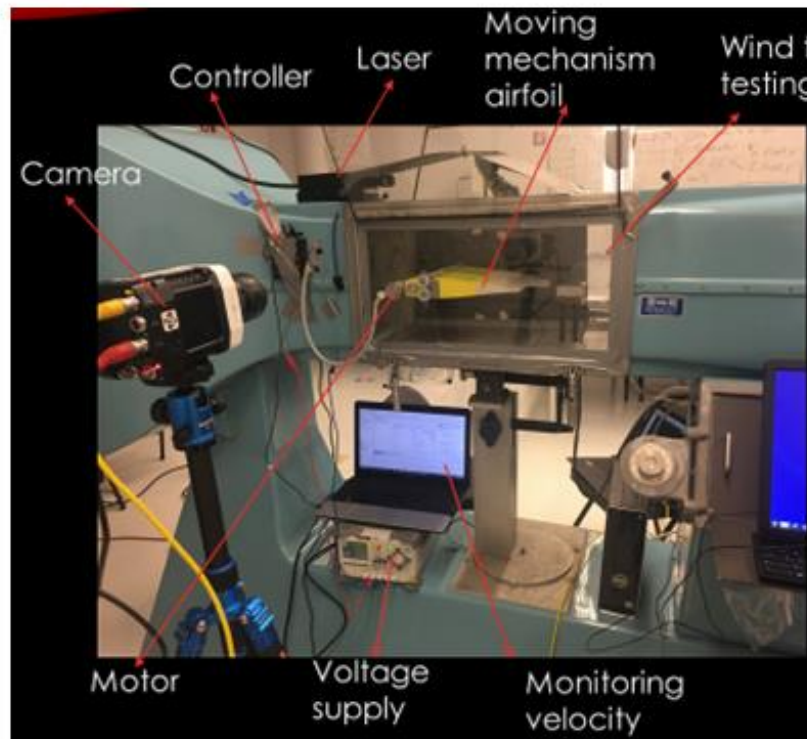


Figure 18: The complete testing configuration mounted and ready for experiments

### 4. MATHEMATICAL FORMULATION FOR POST EXPERIMENT ANALYSIS

The aerodynamic forces and moments on the body are due to only two basic sources; pressure and shear stress distribution over the airfoil. Pressure acts normally on the surface and shear stress acts tangentially on the surface due to friction between the body and the air.

V∞ is the relative wind called freestream velocity which is far ahead of the airfoil. Lift is perpendicular to V∞ and Drag is parallel to V∞ [9].

The chord length (c) is the distance from the leading edge to the trailing edge of the airfoil. Normal force is perpendicular to the chord and axial force is parallel to the chord.

The angle of attack α is the angle between chord length and V∞. Also, it is the angle between Lift and Normal and between Drag and Axial. The geometrical relation between these two sets of components is

$$L = N * \cos \alpha - A * \sin \alpha \qquad (1)$$

$$D = N * \sin \alpha + A * \cos \alpha \qquad (2)$$

To get the Lift and Drag this project took data of the Normal and Axial Forces from the Wind tunnel at each 100 rpms and calculated the Lift and the Drag using equations 1 & 2.

Lift coefficient: $\qquad C_l = \dfrac{L}{q_\infty * Area}$ (3)

Drag coefficient: $\qquad C_D = \dfrac{D}{q_\infty * Area}$ (4)

Pressure coefficient: $\quad C_p = \dfrac{p - p_\infty}{q_\infty}$ (5)

The density ($\rho_{Air}$) and velocity ($V\infty$) are in the free stream dynamic pressure ($q_\infty$) as

$$q_\infty = \frac{1}{2}\, \rho_{Air} * V_\infty{}^2 \left(\frac{m}{s}\right)$$ (6)

$$q_\infty = P_0 - P_s = \rho_{water} * g * \Delta H \ \left(\frac{N}{m^2}\right)$$ (7)

where; $\rho_{Air} = 1.225 \frac{kg}{m^3}, \rho_{Water} = 1000 \frac{kg}{m^3}, P_0 = \ total\ pressure,\ P_s = static\ pressure$ , and $g$ is gravity.

The dynamic pressure, which is the difference of total pressure and static pressure, is used to calculate the air flow speed in the wind tunnel using manometer pressure differences by plugging pilot tube into the wind tunnel testing area. For stalling velocity calculated by $C_{l,\ max}$ and maximum velocity calculated by $C_{d,min}$.

$$V = \sqrt{\frac{q_\infty}{\frac{1}{2}\rho_{Air}}}\ \left(\frac{m}{s}\right)$$ (8)

Aerodynamic coefficients are important engineering quantities that design the performance of the airplane. Therefore, the lift and drag coefficients were calculated using equations 3 & 4.

$C_l$ increases with angle of attack; it reaches the peak and then drops off. To maintain steady, level flight the airplane's lowest velocity is related to $C_{l,\ max.}$ Level flight is when Lift=Weight.

$C_l$ changes due to changing speed; it decreases as $V_\infty$ increases. As the speed goes faster, angle of attack must be smaller in order not to stall the airplane. At high speeds, airplanes must be lower angle of attack and at low speeds airplanes are a high angle of attack, at specific $C_l$ required at that velocity. The important part is to maintain the lift at low drag as possible. This is the reason $C_l$ values are important and $C_d$ values are also changing due to $V_\infty$. To measure the aerodynamic efficiency, lift to drag ratio is considered.

$$\frac{L}{D} = \frac{q_\infty * Area * C_l}{q_\infty * Area * C_d} = \frac{C_l}{C_d}$$ (9)

The higher the ratio, the better is aerodynamic efficiency. The aerodynamic coefficients are very important in the performance analysis of the airfoils.

$$Re_x = \frac{\rho \, V \, L}{\mu} \qquad\qquad (10)$$

$$V_D = r * \omega \left(\frac{m}{s}\right) \qquad\qquad (11)$$

## 5. DISCUSSION OF THE RESULTS

### Table 1 - Original airfoil at 0° and 2° angle of attack for lift coefficient along with Reynold's number

**Table 1 discussion:** The results show that with a higher Reynold's number, which is high flow velocity, the better data is obtained and these results demonstrate how the lift coefficient gets higher with clarity to understand. However, at a low Reynold's number, the data is not clear enough.
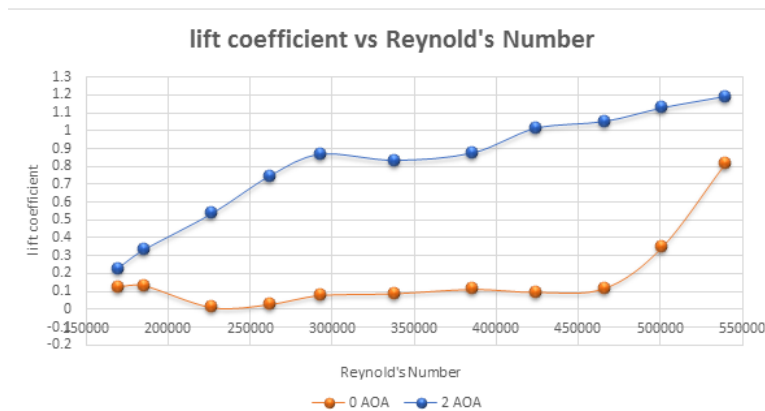


Also, the difference of 0° angle of attack and 2° angle of attack shows that the 2° angle of attack has a higher lift coefficient than the 0° angle of attack. However, the higher velocity of the airflow for the 0° angle of attack give 0.8 for lift coefficient, which is almost the same with half airflow velocity for 2° angle of attack, and by taking the error into consideration, the data is not clear enough, but it still helps to understand the difference.

### Table 2 - Original airfoil at 0° and 2° angle of attack for Drag coefficient along with Reynold's number
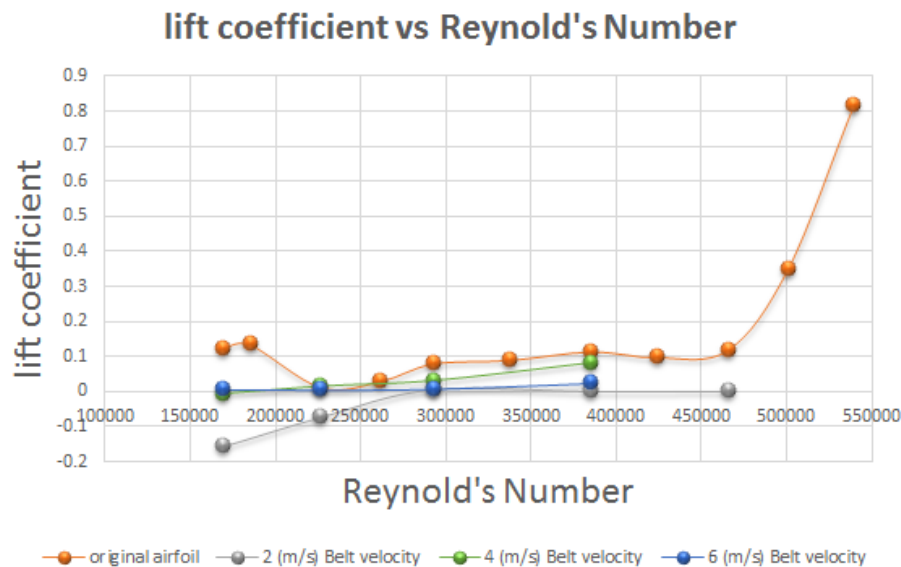
**Table 2 discussion:** The results show that with a higher Reynold's number, which is high flow velocity, the data is clearer and demonstrates how the drag coefficient reacts.

Also, the difference of 0° angle of attack and 2° angle of attack shows that the 2° angle of attack has a higher drag coefficient which is 0.62 than the 0° angle of attack which is 0.01.

The graph shows that the different angle of attack produces a large difference in the drag coefficient, which can be seen in the 0° angle of attack which has an almost 0° drag coefficient with a high Reynold's number. However, the data is not clear enough, but it still helps to understand the difference between the angle of attack and how it reacts with a high Reynold's number.

Drag coefficient vs Reynold's Number

— 0 AOA   — 2 AOA
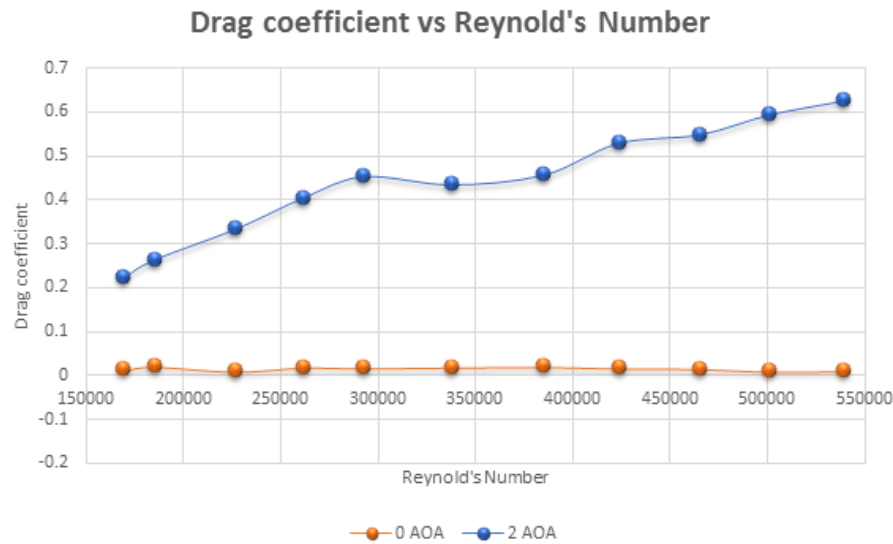
**Table 3 – Force coefficient along with Reynold's number at 0° angle for the original airfoil and the conceptual Airfoil with a 2 (m/s), 4 (m/s), and 6 (m/s) for the belt velocity.**
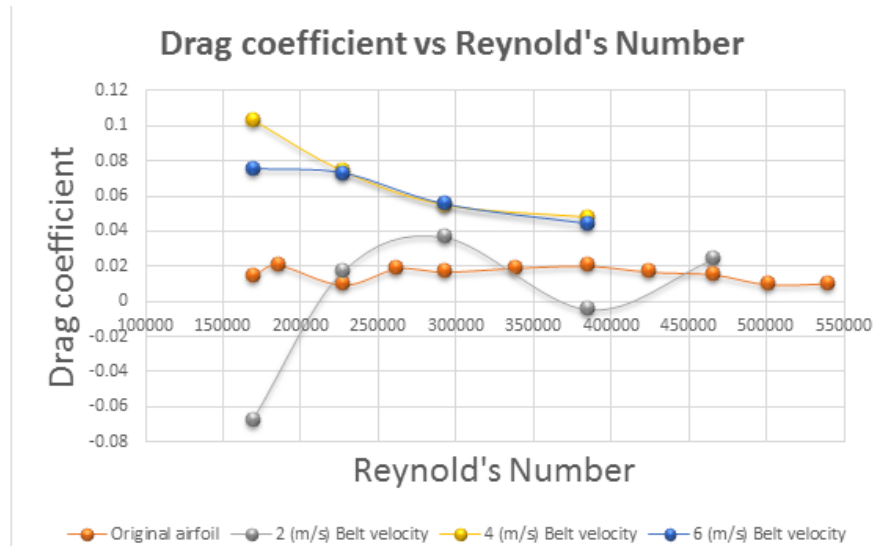


lift coefficient vs Reynold's Number

— original airfoil   — 2 (m/s) Belt velocity   — 4 (m/s) Belt velocity   — 6 (m/s) Belt velocity

**Table 3 discussion:** The results show that with a higher Reynold's number the better data can be obtained, and it shows how the lift coefficient gets higher and is clear to understand. However, at low Reynold's number the data is not clear enough because of high error, especially for the conceptual airfoil, due to the vibration of the system. Moreover, the vibration of the tail increases at a high flow speed, which is the reason that the lift coefficient of the conceptual airfoil is lower than that of the original airfoil.

The table shows inconsistent values, the first point on the graph shows that the belt at 2 m/s has the lowest value, while the original airfoil has the highest value of lift coefficient. From approximately 150000 to 400000 value of Reynolds number, the values of lift coefficient are close, they fall between 0 to 0.1 which is relatively low. After 400000 Reynolds number, it was

233

difficult to collect data for the moving mechanism, due to the high air flow that increased the friction of the belt that caused it to stall, but the data of the original airfoil shows high increase in lift coefficient.

**Table 4 – Drag coefficient along with Reynold's number at 0° angle for the original airfoil and the conceptual Airfoil with a 2 (m/s), 4 (m/s), and 6 (m/s) for the belt velocity.**



**Table 4 discussion:** The higher the Reynold's number the better the data obtained and the drag coefficient is clear to understand. However, at a low Reynold's number the data is not clear enough, due to high error at low air speed, especially for the conceptual airfoil, due to the vibration of the system. Moreover, the vibration of the tail increases at a high flow speed, which is the reason that the Drag coefficient of the conceptual airfoil is higher than that of the original airfoil.

The table shows inconsistent values; the first point on the graph shows that the belt at 2 m/s has the lowest value while the 4 m/s has the highest value of drag coefficient. From approximately 150000 to 200000 Reynolds number the values of drag coefficient are close, and they fall between -0.06 to 0.1 which is relatively low. At approximately 300000 Reynold's number, the values of drag coefficient are relatively close and they fall between 0.02 to 0.06. After 400000 Reynolds number, it is difficult to collect data for the moving mechanism, due to the high air flow, which increases the friction of the belt that caused it to stall, but the data of the original airfoil shows that the drag value is approximately the same.

When comparing the tables of the moving mechanism of both 6 m/s and 4 m/s belt velocity, the results show that they are the same from 220000 to 380000 Reynold's number.

## 6. CONCLUSION

In conclusion, the flow visualization helped the team understand the flow around the airfoil. However, the wind tunnel data showed multiple sources of error due to the wind tunnel balancing issues and the airfoil tail vibration that affected the balance reading. Flow visualization shows that the gap between the moving mechanism and the airfoil tail caused vibrations associated with the turbulent flow, which requires further study. However, the simulation study proved that the moving surface mechanism improved both the lift and the drag forces on the airfoil. The pressure distribution and velocity magnitude of the simulation provided an insight into how the implemented mechanism affected the performance of the airfoil. Overall, this research helped to provide more understanding of the aerodynamics of the airfoil. This research is also instrumental in the implementation of a design in real life and revealed to us how to manage time, troubleshoot problems, and solve these issues.

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# Automated Mechanical Closure Device for Subway Flood Protection

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## ABSTRACT

A Mechanical Closure Device, or MCD, is a flood protection device that is designed to protect ventilator shafts and subway tunnels and underground utilities from flooding. It is designed to support a load equivalent to 14 feet of water from the top of the grating, and reduce the leakage of flood water to about 0.3 gallons per minute. During normal operations, the MCD doors remain in their open position to allow air to freely flow through. When conditions warrant the risk of flooding, a team of personnel is sent to each MCD unit to manually close the MCD doors using a hook tool. Once floodwater has been drained from the MCD, the doors can be opened safely.

In this project, an MCD with linear actuators to control the doors will be designed in CATIA, followed by the production of a prototype about two-thirds of the original size. In addition, analyses, such as stress, pressure, force, temperature, mass, and air flow will be conducted both by hand and in CATIA. Accomplishment of this design task requires determining the materials needed for the prototype, purchasing the actuators that will be used, as well as determining how the actuators will be controlled. The final goal is to have a working prototype in which two actuators control the movement of each door.

## 1.  INTRODUCTION

Flooding is one of the numerous challenges that the subway system in New York City has to endure. One example was in August 2007, when a large unprecedented storm system, producing rainfall amounts ranging between 1.4 and 3.5 inches within a two-hour period, caused flooding in low-lying areas of the city, primarily eastern Queens and parts of Brooklyn (Fig.1). This resulted in the flooding of subway tunnels and stations in those areas which caused service

236

shutdowns, delays, overcrowding, and service reroutes that persisted throughout the day, affecting over two and a half million commuters. As a result, the Metropolitan Transportation Agency (MTA) contracted the design of stainless steel raised modules to be installed on top of existing gratings in flood-prone areas to ensure there would not be a repeat of what occurred in 2007 [1].



**Figure 1: Hillside Avenue subway line flooding during 2007 storm**

Perhaps the most notable flood event was Hurricane Sandy in 2012. During that storm, several subway tunnels were flooded, initially disrupting service for nearly a week and costing the agency about $5 billion in damages. One station in lower Manhattan was even flooded up to the ceiling [2]. Superstorm Sandy proved that the areas classified as Zone A and B were vulnerable to flooding from similar storms in the future [3]. One of the major projects to protect the system from flooding was the contract for Mechanical Closure Devices, or MCD's, ranging from $1 to $5 million, as part of the Sandy mitigation project. The function of an MCD is to keep subway ventilation systems open during normal operations, but to close the vents when there is a risk of coastal flooding. Currently, there are thousands of these units installed in the flood-prone areas of the city.
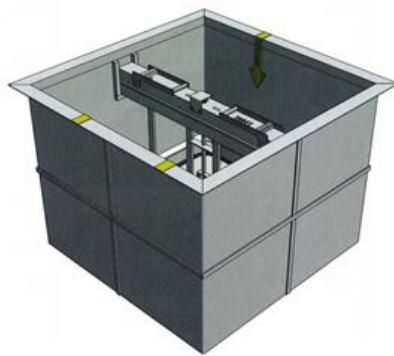


**Figure 2: Left: 3D isometric view of MCD**

When conditions warrant a risk of flooding, a team is sent to the sites where the MCD's are installed. In order to close the doors of the MCD, one person for each door, uses a uni-tool with a
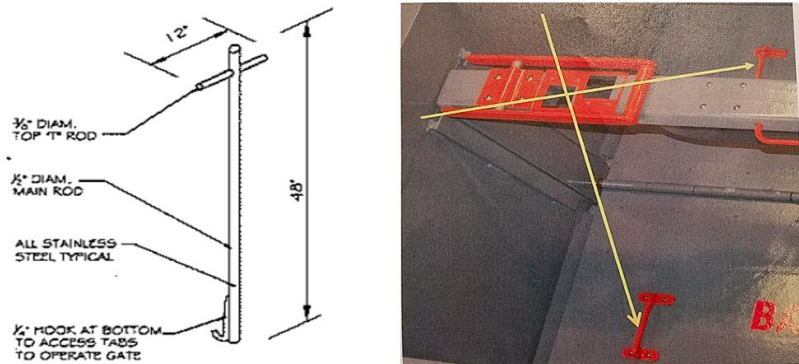


**Figure 3:** *Left:* **The uni-tool used to open and close the MCD flood panels.** *Right:* **The yellow arrows show where the uni-tool hook comes into contact with the door handles.**

hook, shown in Fig. 5, to slide underneath the gratings until it comes in contact with the handles of the doors. The door is then pulled with the tool until it locks into position   One issue with this method is that it can be difficult to know when the hook of the pole comes in contact with the door handle and might require guidance, such as pointing a flashlight at a handle to let personnel know where the handles are. This process takes an estimated 3 minutes for one MCD unit and an hour or two for all units in the city. Costs are estimated to be in the thousands or millions of dollars in building and preparations [5].

## 2.  OBJECTIVES OF THE PROJECT

The main objective of this project is to automate the process of opening and closing the flood panel doors of the MCD, thereby eliminating the use of the uni-tool and streamlining the process. The options are automation of the existing doors or design of a new door system which leaves the original shell design intact. To automate the doors, we will use an electrical linear actuator, a device used for moving or controlling a mechanism or system.

The first task involved in automation is to design the MCD on CATIA based on the original specifications, materials, and weight, and test the effect of distributed forces and temperatures on the structure, based on actual data and hypothetical data of the weight of flood water.  The new design should also not cause a dramatic decrease in air flow. In addition, pre-designed actuators will be tested in CATIA to determine their proper location, speed and motion to determine whether or not the actuators meet our criteria for purchase.
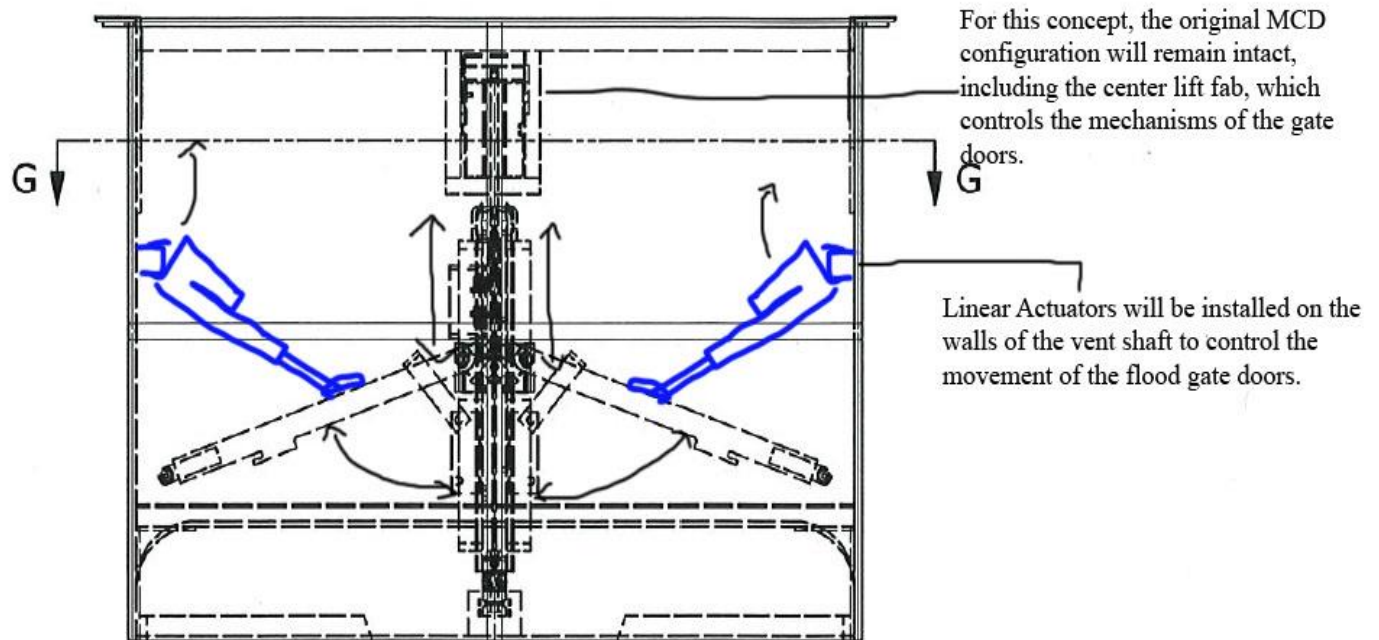
## 3.   ENGINEERING REQUIREMENTS

**Mock-up MCD:**
  (1) Vent shaft box must be made of 1/4" grade 5052 aluminum material [6]
  (2) Gate panels (flood doors) must be made of 3/8" grade 5052 aluminum material
  (3) Must include four lifting lugs necessary to lift entire unit
  (4) Model must be coated in Amercoat 240 paint
  (5) Requires a total of four linear actuators to be used, with two controlling each door.

238

(6) The actuators must have a maximum stroke length of 8".
(7) At most, a force of 25lbs is required for the actuators
(8) The speed of the actuator at maximum force must be 1.37"/sec

## 4.    TECHNICAL APPROACH

**Generating Design Concepts:**



For this concept, the original MCD configuration will remain intact, including the center lift fab, which controls the mechanisms of the gate doors.

Linear Actuators will be installed on the walls of the vent shaft to control the movement of the flood gate doors.

**Figure 4: Original MCD with added actuator**

**Design Concept 1:** Original MCD configuration with actuators installed;
- No changes would be made to the actual MCD, except for the installation of actuators as seen in Fig. 4.
- The rest of the design stays the same, in terms of how it previously functioned.
- Problem with use of this design: Unknown if current MCD configuration will support actuators. Also, it is unknown how the direction and mechanism of the original doors works

**Design Concept 2**: Brand door system with original vent shaft shell intact;
- A 'flaps' system, similar to the devices used on the wings of an aircraft, would be used in which there is a continuous row of three doors, automated by actuators as seen in Fig. 5
- During normal operations, the doors are in their open position at an angle of 45 degrees
- Problem with use of this design: There is no guarantee that air flow will not be reduced due to the configuration of the flaps system.

239
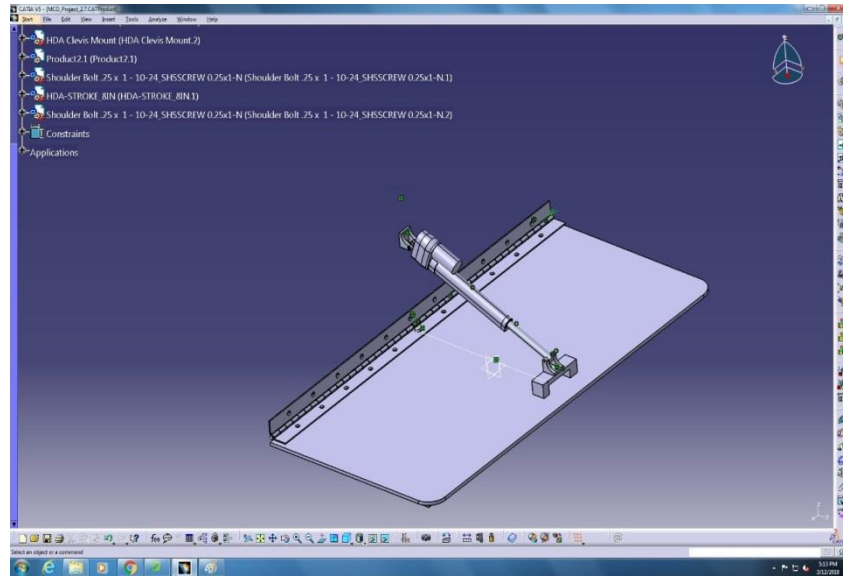
**Figure 5: New door with flaps**

**Final Design:** Two MCD doors automated by Actuators;
The final design will be similar to concept 1, except the center lift fab mechanism will be entirely replaced with two installed actuators, one operating each door.
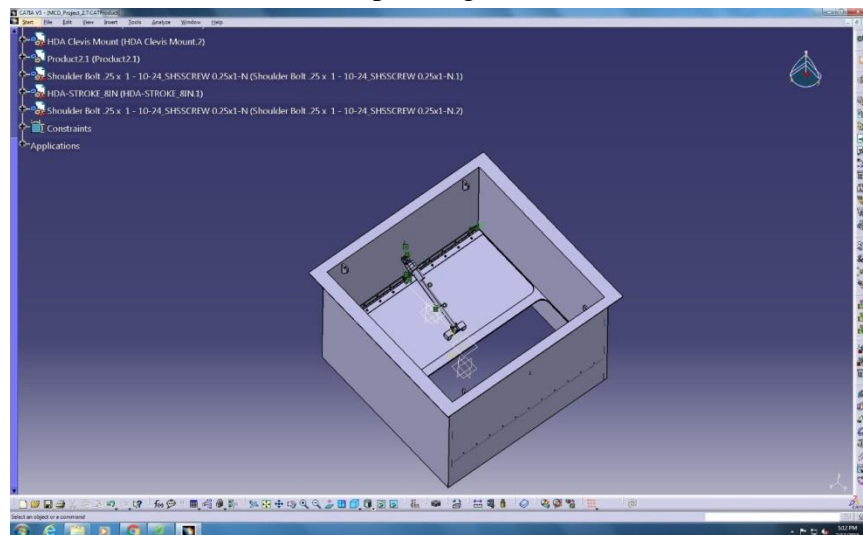


**Figure 6: Final design of MCD**

During normal operations, the doors would remain open at an angle of 45 - 60 degrees, so the air can flow in and out as seen in Fig. 6. Using a control system connected to the main power grid, the actuators will control the doors. This system can be implemented either wirelessly or through a main grid switch which takes little time or effort to perform the operation.

## 5. APPLICATION

This project would be beneficial to the city of New York and the MTA. First, it will help prevent a catastrophe similar to what happened during Hurricane Sandy. Second, this will make MCD operations more streamlined, simple and modern. In addition, this project will be a first step towards full remote operation, through which all MCD's in the city will be operated and monitored by a computer in the MTA's control room.

## 6. PROJECT UPDATES

At this point, the project has gone through all the steps and is at its final stage of computer testing and design. The main MCD shell has been created, as well as the actuators, doors, hinges and bolts. Now all the parts are being connected and animated to work and flow as one piece in CATIA. Once that stage is done, the main testing and model building section will begin. In CATIA many different forms of testing will be completed, including the strength of the parts and shell, the stress, the pressure, the bending, the failure and the tolerances of all the parts in the project. This testing will demonstrate how the new design will keep up with the most extreme conditions, and how it compares with the original shell design. The actual scale model building process is taking shape, and the actuators are next on the agenda to purchase.

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