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The Challenge of Challenges: Virtual Engineering Design Challenges During the COVID19 Pandemic (Evaluation)

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Introduction

Engineering design competitions for K-12 students have been a consistent recruitment strategy for many universities. Most of these activities also serve as a learning experience for students as they consider future career paths. In the recent past, a number of these competitions and experiences have involved the design, implementation and use of drones.

In Spring 2020 after the onset of the COVID19 pandemic, several outreach programs for K-12 students either had to be canceled, postponed or moved to an online/hybrid program [5]–[7]. This paper presents one such program: the Engineering Design Challenge (EDC) at the Armstrong campus of Georgia Southern University which had to move to a virtual/hybrid environment in both Fall 2020 and Spring 2021. The literature as presented in the next few paragraphs, however shows no drone based program that was conducted as an online/hybrid program.

The 'Take Flight Robotics' program held at the University of Maryland, Baltimore County was a weeklong summer enrichment program that introduced local high school students to the basic concepts of unmanned aerial vehicles (UAVs) [1]. Students were taught how to design, build and fly their own quadcopter. The program was an ideal learning experience for students as they were introduced to key aerospace and aerodynamics concepts such as lift, drag, thrust, engineering design, 3-D printing, mechanical and electrical systems and computer programming. Another program, the Drone Exploration Academy project at Elizabeth City State University provided 6th-12th grade students a series of Friday sessions and a weeklong summer session in which they were introduced to UAV mission planning, field investigation and designing ground and aerial vehicles to meet specifications [2]. The informal learning environment introduced students to concepts such as equilibrium, aerodynamics, lift, drag, 3D printing and the engineering design process. A team at the Georgia Institute of Technology has developed an informal learning curriculum as part of the Innovative Mars Exploration Education and Technology program [3]. The program is an effort to provide high school students with a two-phase summer camp curriculum: instructional phase and collaborative challenge phase so students can work on a hands-on team project after learning foundational concepts. The program introduces students to ground and aerial robotics through LEGO Mindstorm kits and off-the-shelf quadcopter kits. The parts for the design challenge, such as LEGO bricks, wheels and blades are modeled using the CAD program CATIA and created using 3D printers.

While the use of drones has increased in popularity, there is still an underrepresented minority group among the general student population who are not adequately exposed to their use. For example, programs such as VEX Robotics Competitions have been popular at K-12 schools for a number of years. However, many students are not equipped with the background knowledge to do well at these competitions. This issue is addressed by a STEM training program developed at the Vaughn College of Aeronautics and Technology [4]. The program provides intensive training to middle and high school students over summer and winter breaks to increase their capability in VEX Robotics. Another program, at the University of Colorado, Boulder worked with low-income middle school students in a 16-week, after school engineering program [8]. Students were posed with the following problem: to provide relief to a town that has been damaged and isolated due to a national disaster. UAVs were to be used as the primary tool, introducing student learners to problem solving, control engineering and image processing early in their curriculum. A part of this program also included the design of custom “skyhooks" for supply delivery [9]. Students were introduced to concepts in 3D modeling to help them visualize their designs. In another version of the program, these skyhooks were also printed on a 3D printer [10]. Additionally, a team at the New York University has a creative example of introducing 9th grader students to quantitative research via a lab based AR drone activity [11]. The lab especially targeted the special learning needs of students with autism spectrum disorders (ASD) who composed 12% of the student body.

The applications of drones have also been diversified to address sustainability issues. The team at Old Dominion University used drones in a summer residential education program for high school students with a focus on climate change and sea level rise issues [12]. The program used LEGO Mindstorms, Kamigami and Cozmo robots for the three-day workshop.

As mentioned previously, this paper presents an overview of a drone-based design challenge developed by the first author at the Armstrong campus of Georgia Southern University. The program had to be conducted as a hybrid/online one in 2020 and 2021 due to COVID19. The following sections present the details of the EDC 2020, EDC 2021, Discussions on Lessons Learned, Conclusions and Acknowledgements.

Engineering Design Challenge (EDC) 2020: Eagle-ROAR

The Armstrong campus of Georgia Southern University has held EDCs since 2014. The first author had the idea of a drone-based EDC in 2016, but it was not pursued due to the cost of drones at the time. However, by 2019 the cost of a mid-sized drone dropped to less than $300, making the purchase feasible for the challenge. In Spring 2019, the first author submitted proposals to the NASA/Georgia Space Grant Consortium and Gulfstream Aerospace Corporation to fund EDC 2020: Eagle-ROAR (Remotely Operated Aerial Reconnaissance). Eagle-ROAR was a novel engineering design competition that engaged high school students through the use of unmanned aerial vehicles (drones), in the application of fundamental mathematics and physics, and design engineering. The project was inspired by the broad popularity of terrestrial drones and NASA's Mars 2020 rover mission, which included an autonomous helicopter (drone). The objectives of Eagle-ROAR were to:

1. Engage Eagle-ROAR participants in a hands-on engineering experience that leverages their prior STEM knowledge to develop a deeper understanding of STEM concepts applied to aerial flight and engineering design.
2. Increase the pipeline and diversity of students interested in STEM fields relevant to Georgia Southern University and NASA.
3. Enhance Eagle-ROAR participant's soft skills applied to the presentation of technical content.
4. Leverage Eagle-ROAR participation for the increase in the local community's awareness of NASA related topics and Georgia Southern University STEM education opportunities.

Each Eagle-ROAR team was provided with a stock drone and tasked with learning how to fly it and using CAD software to design a 3D printable grappling system that attaches to the drone. The teams also had to design their own payload that was required to incorporate a wire clothes hanger. The drone-based grappling system was required to transport and deliver the wire clothes hanger payload and a separate 3D printed payload provided to each team. The teams evaluated their grappling designs based on prioritized criteria and trade-offs that account for a range of constraints, including cost, reliability, and aesthetics. These tasks met the following Next Generation Science Standards (NGSS) adopted by the Georgia Department of Education [13]:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The high school teams were coached by their STEM teacher, a Georgia Southern engineering student (serving as project coach), and a practicing engineer from local companies (serving as a project mentor). Table 1 details key milestones for EDC 2020.

Table 1: Timeline of Pre-COVID EDC 2020 Activities.

Spring - Fall 2019	Details of EDC 2020 were developed
Dec 2019 - Jan 2020	Recruiting of EDC teams; Completion of waivers and pre-test by teams.
Jan - April 2020	EDC teams working on project
April 25, 2020	EDC 2020: Eagle-ROAR Competition and post-test completion

The EDC 2020 details noted in Table 1 consisted of the creation of competition rules, evaluation and selection of a drone, grappling attachment and payload feasibility studies, developing a pre-test, and the creation of primers for EDC teams on CAD software (to help them design their attachment) and drones.

EDC 2020 Competition Details

The competition consisted of an indoor head-to-head race in a random seed double elimination style tournament in which the teams had to use their drones to deliver up to four payloads across the drone airfield (see Figure 1), through a 30 inch diameter hoop, and deposit the payloads in the designated landing locations in as little time as possible. The payloads had to be picked up by the 3D printed grappling attachment designed by the teams. The grappling attachment could only pick up one payload at a time, secure it during flight, and release the payload in a controlled manner. The teams had to design and construct three wire hanger-based payloads and were also provided with a fourth tripod payload (See Figure 2). The teams were also instructed to minimize the cost of their grappling attachment by minimizing the volume of material used for the design. All drone flights were required to be indoors in accordance with FAA regulations.

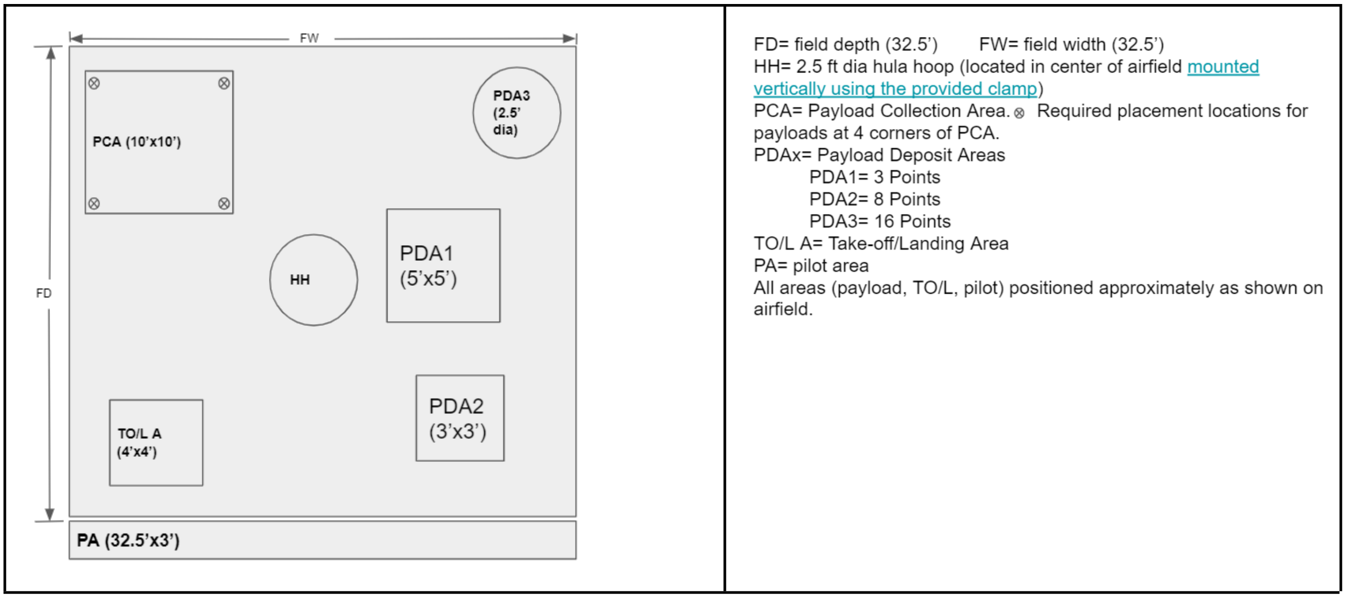


Figure 1. The airfield and legend for the EDC 2020 competition.

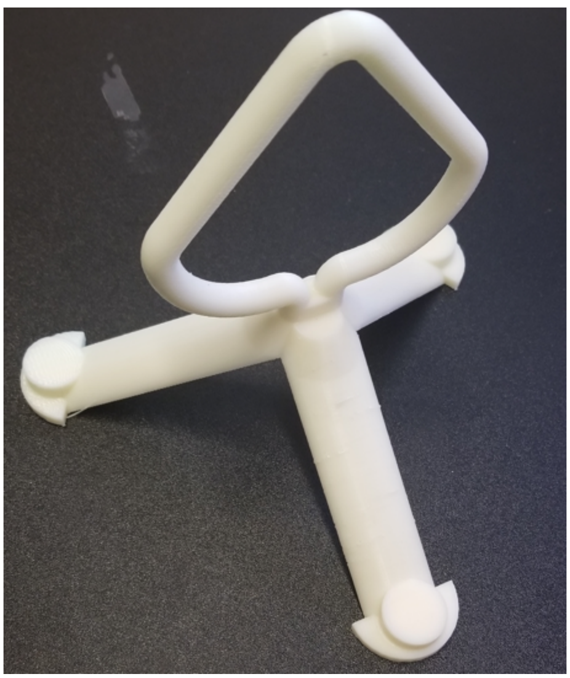


Figure 2. 3D printed tripod payload given to each EDC team.

The drone grappling system attachment for carrying the payloads had to be solely made of 3D printed parts, and designed to fit securely to the drone for attachment. No adhesives, fasteners, strings, or other means were allowed for construction or attaching or assembling the grappling attachment.

Drone and Payload Evaluation

A major challenge for a drone themed competition was to select a suitably priced drone that was capable of accommodating an attachment and with sufficient payload capacity. Seven preliminary drones were evaluated with the finalist drones selected based on the criteria shown in Table 2.

Table 2. Drone evaluation criteria and scoring

Criteria	Drone A Score	Drone B Score
Actual Battery Life	1.5	1
UI Ease of Use	2	2
Flight Stability	1	2
Durability	2	2
Handling	1	2
Safety	1	1.5
Ease of landing	1.5	0.5
Takeoff	1	2
Ease of learning how to fly	1.5	2
Cost	2	1.5
Total	**14.5**	**16.5**
Based on rating scheme: Poor=0, Satisfactory= 1, Excellent=2		

Drone B was selected for further evaluation (e.g., payload capacity and adaptability for an attachment). A prototype attachment (shown in Figure 3) was designed and 3D printed to verify Drone B's flight capabilities while carrying the 3D printed tripod payload (shown in Figure 2).

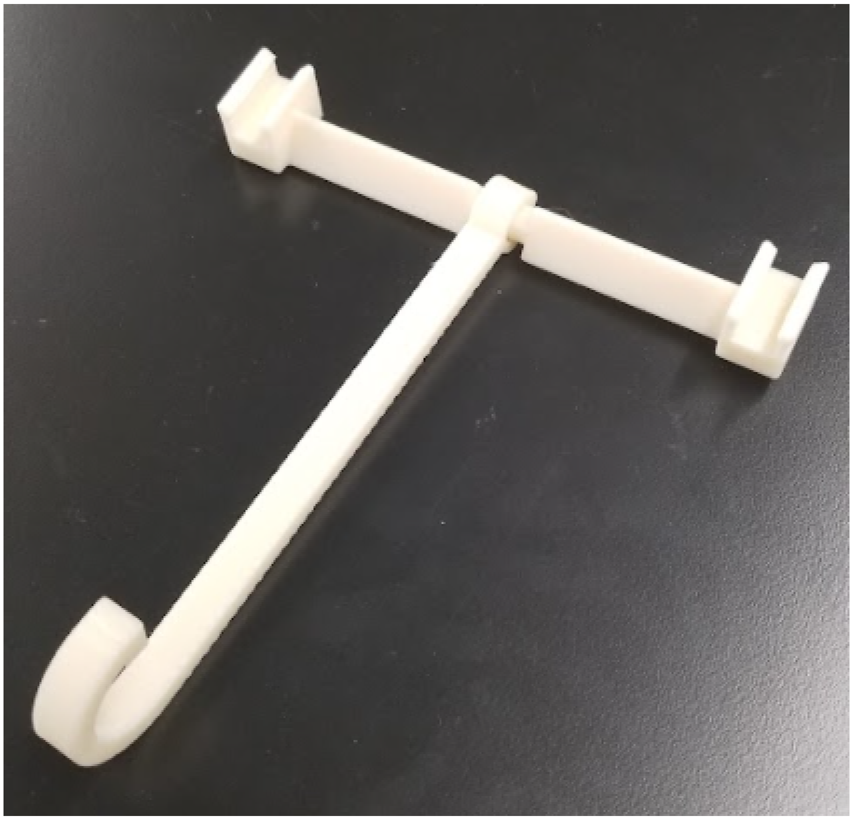


Figure 3. Prototype 3D printed grappling attachment

EDC 2020 Team Development

A 10 question multiple choice pre/post test was developed (See Appendix A) to assess student learning gains related to drone components and the physics of flight. The EDC teams were given access to the “Drone School" document after the pre-test was administered. “Drone School” provided details about drone components, the physics of drone flight (which references concepts of NGSS- HS-PS2 Motion and Stability: Forces and Interactions [13]), and how to fly drones. The teams were also given access to free CAD software and training resources to create their drone grappling attachment devices.

By February 2020, seven high school EDC teams (36 high school students) were meeting with their project coaches and mentors to work on their designs and practice flying their drones. Despite our recruiting efforts, only one Title 1 school completed the application process for establishing an EDC team. Title 1 schools were targeted for participation to meet Eagle-ROAR Objective 2 (discussed earlier). Little did we all know that within less than a month, all K-12 schools and universities would switch to virtual classes due to the COVID19 pandemic.

EDC 2020's COVID19 Shutdown and Rebirth

Georgia Southern University switched to virtual learning during spring break (mid-March) of 2020 following the same earlier switch by area K-12 schools. It was a sad but easy decision to postpone EDC 2020 given all the uncertainty of what would happen next. By August 2020, Georgia Southern University classes returned to a hybrid model, while K-12 schools remained mostly virtual. The original seven EDC teams were surveyed regarding their interest and capability to participate in a virtual version of the EDC 2020 competition. Two of the original schools expressed interest and a new home school EDC team was created based on the third author's contacts as a former home school student. With a total of 3 teams (12 students), EDC 2020: Eagle-ROAR was reformulated as a virtual competition.

Teams were provided with video conferencing resources (e.g., Google Meet, Zoom, etc.) and instructed to meet virtually. Also, instead of an in-person race, teams were required to create a video presentation of their grappling system and wire hanger payload designs, and discuss the mechanics of drone flight based on the rubric shown in Table 3 .

Table 3. Video Presentation Scoring Rubric

Scoring Category	**Weight**
Content (PD1-6)	40%
Organization	20%
Delivery	15%
Creativity/Design Innovation	25%
Total	**100%**

Teams were also provided with a tentative schedule of activities for completing the challenge (see Table 4) along with suggestions for the presentation content (PD1-6, See Appendix B).

Table 4. Suggested project milestones

Week of	Milestone (Remember to creatively document each milestone for presentation use)
Sept 28	Set up virtual team meeting times and dates. Work on PD 1-3, Brainstorming PD 4 & 5
Oct 5	Complete presentation content for PD 1-3. Continue design development for PD 4 & 5
Oct 12	Continue design development for PD 4 & 5. If able, develop SWKs model for PD 4. Finalize design for PD 5.
Oct 19	Continue design development for PD 4 & 5. If able, finalize SWKs model for PD 4 and optionally submit for 3D printing
Oct 26	3D printed models for PD4 returned to teams (if applicable). Video presentation content completed, presentation practice, final recording and editing.
Nov 2	Video presentation editing. Sharing of video presentation via Google Drive (Nov 4, 2020 @ 5pm).
Nov 7	EDC 2020 Eagle ROAR Virtual Competition via Zoom.

As noted in Table 4, teams were given the option to submit their CAD models for 3D printing and allowed to test their 3D printed designs with their drone (in a socially distant manner).

Results of EDC 2020

The three EDC teams successfully developed and tested their grappling attachment, wire hanger payloads and video presentations. Figure 4 shows two examples of grappling attachment designs. All the designs seemed to function as expected, but due to this being a virtual competition, it is unknown how they would have performed in an actual head-to-head race. In a racing scenario, the team drone pilot would obviously play an equally critical role in the overall performance. Nonetheless, a panel of engineers from industry and academia evaluated the presentations based on the rubic shown in Table 3. Monetary prizes were awarded to the team with the best overall score and for the most innovative design.

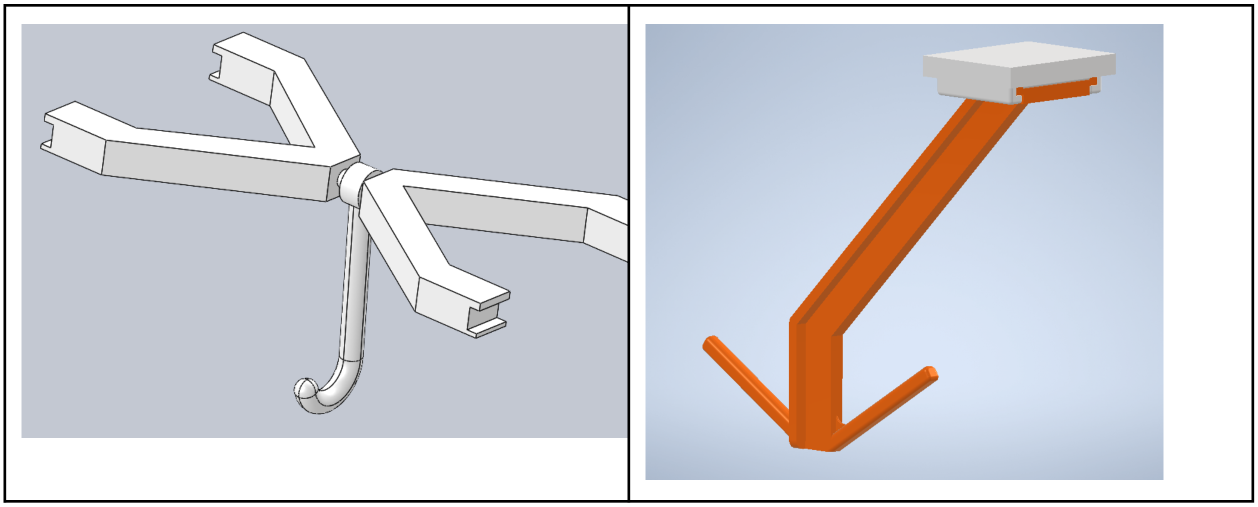


Figure 4. Examples of two EDC team's grappling attachment designs.

EDC 2020 was evaluated based on the results of pre/post-tests (see Appendix A) and a Likert scale self reporting survey of the participants. The post-test was given to all participants after the virtual presentation. A statistical analysis was conducted on the pre and post-test score data for 2020. A Chi square analysis was used to compare the number of post-test score improvements compared to decreases. A Wilcoxon Signed Ranks Test was used to compare the magnitude of test score change between pre and post-test scores. The statistical significance was set at α=.05.

Ten of the twelve participating students completed the pre-test and post-test. While 80% (n=8) of the students demonstrated a post-test score increase compared to 20% (n=2) of the students demonstrating a post-test score decrease, the difference was not statistically significant ($\chi2$=3.6, P=.058). Of the 8 students revealing a post-test score increase, 87.% (n=7) of them showed a ≥2 point improvement, whereas the post-test score decrease was 1 point for both students. The overall magnitude of the test score change (Median=2.0, IQR=2.5) across all participants was statistically significant (Z=2.4, P=.016, r=.76). It was surprising that the post-test increase was not significant even with a clear majority of the students demonstrating a post-test increase. Yet the statistical analysis would have required 9 out of the 10 participants to have a post-test score increase to yield a statistically significant outcome.

The participants were also asked three Likert scale questions in post-test to assess their perceptions of EDC 2020's effectiveness. A Chi square analysis was conducted on the number of participants that either "Strongly Agreed" or "Agreed" compared to "Neutral", "Disagree" or "Strongly Disagree". The statistical significance was set at α=.05. The results of these questions and the P-values are shown in Table 5. The majority of participants felt EDC increased their desire to pursue a STEM career and their knowledge of NASA space missions at a statistically significant level. However, there was an even split between the number of participants that would consider attending the Armstrong campus of Georgia Southern University as a result of the EDC which was not statistically significant. Fortunately, EDC did not discourage students from attending the campus, but there is a need to better connect the campus with EDC activities in post-pandemic iterations.

Table 5. Likert scale self reporting survey results for EDC 2020.

Question	SA	A	N	D	SD	Total	P-Value
My participation in EDC 2020 increased my desire to pursue a Science, Technology, Engineering or Math (STEM) career	58%	25%	17%	0%	0%	100%	.021
My participation in EDC 2020 increased my knowledge about NASA space missions	42%	42%	8%	8%	0%	100%	.021
I am more likely to consider attending the Armstrong Georgia Southern campus for college based on my participation in EDC 2020.	33%	17%	50%	0%	0%	100%	1.00
Legend: SA:Strongly Agree, A:Agree, N:Neutral, D:Disagree, SD: Strongly Disagree							

The post-test also asked participants to share comments about EDC 2020, if they would recommend EDC to other high school students, and how EDC could be improved. Comments about EDC 2020 were mostly positive. Representative examples are shown in Table 6.

Table 6. Representative participant comments about EDC 2020

Participant Number	Participant Comment
1	“Yes, it was a great opportunity to learn more about the engineering world and to work with a team to achieve a set goal and project.”
2	“I would definitely recommend the EDC 2020 to other schools and participants. This competition was very worth it and enjoyable, but I would change the in-person competition. It was understandably online, but I was really looking to fly in the competition. Hopefully future competitions will allow the in person flights.”

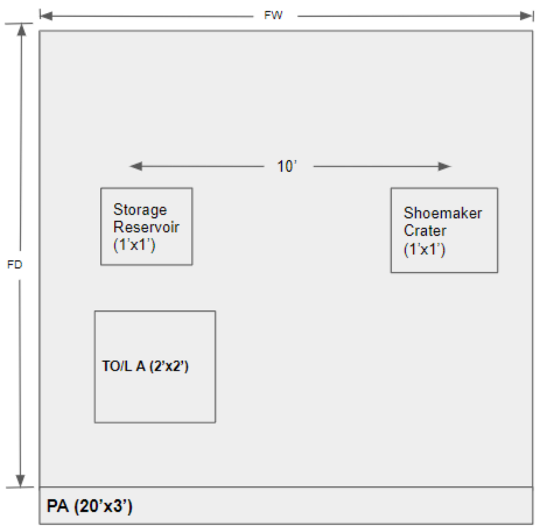
3	"Of course this year is unprecedented but I think that the opportunities given by EDC are very helpful for many local schools, especially for students trying to open their minds into other STEM fields. For example in this challenge there were a lot of elements of the engineering design process put into play, having students research, plan, design, test, and continue that cycle helped them get a more hands-on experience than a traditional classroom setting. In my opinion EDC made the right decision continuing this competition, especially in this year where physical clubs became harder to run. Collaboration for this challenge was accessible through many software that allowed online planning, designing, and video editing which really helped overcome the challenge of the pandemic."

Engineering Design Challenge (EDC) 2021: Eagle-ROAR2

Based on the success of EDC 2020, the return of high schools to hybrid and/or face-to-face teaching, and the NASA ARTEMIS 2024 Program, a follow up drone-based EDC was developed for Spring 2022: Eagle-ROAR2 (Remotely Operated Aerial Recovery). ARTEMIS will return astronauts to the Moon in 2024 and develop the knowledge, technology, and infrastructure to ultimately allow the first humans to reach Mars by 2030. Each Eagle-ROAR2 team was provided a drone (same from EDC 2020) and tasked with learning how to fly it, designing a drone-based, 3D printable tool for excavating and delivering lunar soil. The teams also had to document their engineering design work, perform a kinematic analysis of drone flight and develop a video presentation of their work. The high school teams were mentored by their STEM teacher, a Georgia Southern engineering student (serving as a project coach), and a practicing engineer from local companies (serving as a project mentor). For brevity, the objectives of Eagle-ROAR2 are omitted here, but they were similar to Eagle-ROAR. Additionally, Eagle-ROAR2 also met the Next Generation Science Standards noted in the previous section [13].

EDC 2021 Competition Details

This competition required EDC teams to design a 3D printable Self-Attachable/Detachable Excavation System (SADES) that attaches to the provided drone. The SADES was used to collect, carry and release soil from a lunar crater into a storage reservoir (see Figure 5). The teams were given two, 3-minute long sessions to collect as much soil as possible. However, each team's drone (with their SADES) was flown by an independent drone pilot. This was initially done to limit physical contact of the EDC teams due to COVID19 protocols. But this inadvertently added a real-world engineering design scenario in which the engineering design team is not the end-user. It also allowed for a quasi-return to some type of head-to-head competition activity while maintaining the health and safety of all participants.



FD= field depth (20') FW= field width (20')

TO/L A= Take-off/Landing Area
PA= pilot area
All areas(reservoir, TO/L, pilot) positioned approximately as shown on airfield.

Figure 5. The airfield and legend for the EDC 2021 competition.

The teams were also required to perform kinematic calculations based on a provided video clip of a drone flying horizontally in front of a ruled background (see Figure 6). The calculations included plotting the drone velocity as a function of time and the drone's average horizontal acceleration. This component for Eagle-ROAR2 was added since it could reasonably be completed in remote settings just in case increasing COVID19 cases triggered high schools returning to fully virtual learning later in the school term. Gravel was originally selected to simulate "lunar soil", but was shown to be too difficult to excavate based on the limited thrust force of the drone. Pinto beans were used as the "lunar soil" instead due to its smoother texture.

In addition to the drone, the teams were provided with the drone mass, the maximum payload mass, and other relevant information for their SADES design and the drone kinematic calculations. The teams were also given lunar soil (pinto beans) and reservoirs for testing their designs. Each team was allowed to 3D print two SADES prototypes for testing at their schools prior to the SADES evaluation flight tests with the independent drone pilot. All 3D printing was done at the Armstrong campus of Georgia Southern University and delivered to the teams by the project coaches. The SADES evaluation flight tests were recorded and provided to each team along with the mass of their collected soil for inclusion in each team's video presentation.

Figure 6. Screen capture from the video clip of a drone flying in front of a ruled background.

The video scoring rubric (see Table 7) was provided to the teams and also included suggestions for the presentation content (PD1-6, See Appendix D).

Table 7. EDC 2021 Scoring Rubric

Evaluation Area		Weighting %
Lunar Soil Collection Performance		50
Video Presentation	Content (PD1-5)	30
	Organization	10
	Delivery	10
Total		**100**

EDC 2021 Team Development

A 10 question multiple choice pre/post test was developed (See Appendix C) to assess student learning gains related to drone components and the physics of flight. The EDC teams were given access to the "Drone School v2.0" document after the pre-test was administered. "Drone School v2.0" was an updated version of the document used for EDC 2020; it contained more details on the system of units for forces and kinematic quantities, more discussion of Newton's 2nd Law, and plotting velocity as a function of time. The teams were also given access to free CAD software and training resources to create their SADES. Four high schools participated in EDC 2021 (27 students), and one of these schools had two teams (5 total teams). The project coaches met with their team weekly either virtually or in person. The engineering mentor participation was limited likely due to the ongoing COVID19 pandemic.

Results of EDC 2021

All five high school teams successfully developed functional drone-based excavation systems and created video presentations that were judged virtually. Figure 7 highlights the highest scoring excavation designs (SADES). Each team's drone kinematics analysis, technique, and results varied. All teams were able to plot the drone velocity as a function of time, but only one team correctly extrapolated the drones average acceleration from this plot. The use of video-based kinematic software was not restricted in the EDC 2021 rules. Two teams used a software program for their analysis, but lacked an understanding of the concepts based on their presentation discussion. The results from the 5 teams were not surprising given the unknown physics backgrounds of the students and the extent to which students were required by their teachers to review the Drone School v2.0 document.

A panel of academic and industry engineers evaluated the presentations based on the rubric in Table 7. Monetary prizes were given to the overall winner and for the best video presentation.

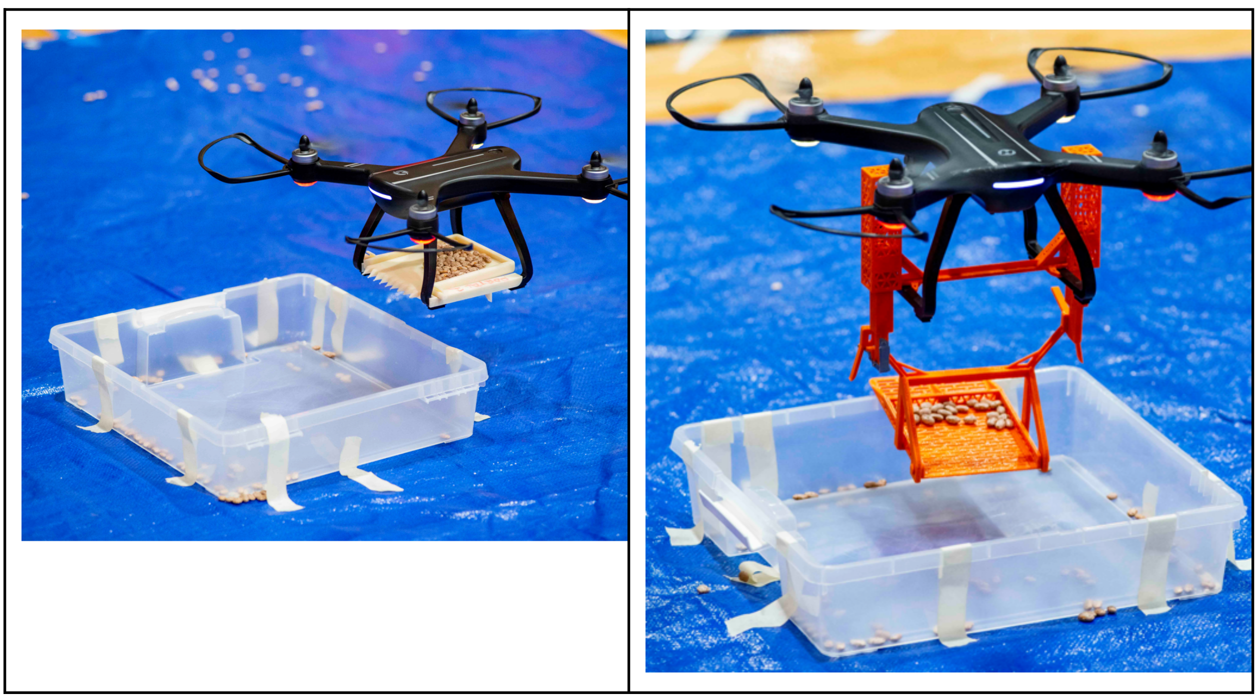


Figure 7. The winning (left) and 1st runner up (right) drone-based excavation designs (SADES).

EDC 2021 was also evaluated based on the results of the pre/post-tests (see Appendix C) and a Likert scale self reporting survey of the participants. The post test was given to all participants after the virtual presentation. A statistical analysis was conducted on the pre and post test score data for 2021. A Chi square analysis was used to compare the number of post-test score improvements compared to decreases. A Wilcoxon Signed Ranks Test was used to compare the magnitude of test score change between pre and post test scores. The statistical significance was set at α=.05.

Twenty-seven students completed the pre-test and post-test for EDC 2021. A significant (χ^2=8.0, P=.018) number of students demonstrated a post-test score increase (55%, n=15), compared to the number of students demonstrating no change (11.1%, n=3) or score decrease (33.3%, n=9). Of the 15 students revealing a post-test score increase, 46.7% (n=7) of them showed a $\geq$2 point improvement, whereas of the 9 students revealing a post-test score decrease (n=9), 77.8% (n=7) had a decrease $\leq$2 points. The overall magnitude of test score change (Median=1.0, IQR=3.0) across all participants was not statistically significant (Z=.84, P=.399, r=.16).

The participants were also asked three Likert scale questions in the post-test to assess their perceptions of EDC 2021's effectiveness. A Chi square analysis was conducted on the number of participants that either "Strongly Agreed" or "Agreed" compared to "Neutral", "Disagree" or "Strongly Disagree". The statistical significance was set at α=.05. The results of these questions and the P-values are shown in Table 8. Similar to EDC 2020, the majority of participants felt EDC increased their desire to pursue a STEM career and their knowledge of NASA space missions at a statistically significant level. Unlike EDC 2020, a greater number of students were either neutral, disagreed or strongly disagreed with their EDC participation making them more likely to attend the Armstrong campus of Georgia Southern University. This result was not statistically significant.

Table 8. Likert scale self reporting survey results for EDC 2021.

Question	SA	A	N	D	SD	Total	P-Value
My participation in EDC 2021 increased my desire to pursue a Science, Technology, Engineering or Math (STEM) career	23%	50%	23%	4%	0%	100%	.019
My participation in EDC 2021 increased my knowledge about NASA space missions	27%	50%	23%	0%	0%	100%	.0010
I am more likely to consider attending the Armstrong Georgia Southern campus for college based on my participation in EDC	12%	23%	58%	4%	4%	100%	.12

2021.							
Legend: SA:Strongly Agree, A:Agree, N:Neutral, D:Disagree, SD: Strongly Disagree							

The post-test also asked participants to share comments about EDC 2021, if they would recommend EDC to other high school students, and how EDC could be improved. Representative examples are shown in Table 9.

Table 9. Representative participant comments about EDC 2021

Participant Number	Participant Comment
1	“Maybe a challenge dealing with circuit”
2	“I would definitely recommend EDC to other high school students. Knowing the restrictions caused by Covid and the FAA, I do not believe that there is anything to really be improved for the EDC.”
3	“Even though COVID restricted it, it would be better to be in person.”
4	“The competition had some flaws. I don't think rules should be changed after the competition starts. This issue caused a lot of confusion. Also the whole idea seemed a little too complex/complicated with the materials and time we were given. I overall enjoyed the challenge it tested my skills on working with other people.”

The comment from participant 4 was in reference to the switch from gravel to pinto beans as the “lunar soil” (discussed earlier in the EDC 2021 Competition Details section). It is never ideal to change the rules after the competition has started. This was an executive decision to make the competition more feasible for teams given the COVID19 restrictions. It was communicated to all teams via email to the coaches and teachers.

Discussion- Lessons Learned

Despite the many inconveniences and limitations of hosting an EDC during a pandemic, there were several positive learning opportunities that would not likely have been discovered otherwise. It seems almost obvious that pre-pandemic, virtual meeting resources could have been used. Yet, the COVID19 shutdown in Spring 2020 forced all area high schools and universities to wholly embrace virtual meetings. This necessity helped to make all stakeholders more open to the utility of virtual meetings. There was now more flexibility in meeting times and accessibility for the project coaches and mentors. In the case of EDC 2020, with teams meeting mostly online for the duration of the project, this exposed the student participants to a real-world scenario experienced by multinational engineering design teams that also collaborate remotely.

Moving to a virtual final competition event for EDC 2020 also led to the idea of having pre-recorded team presentations to minimize unexpected issues from teams and/or judges being unable to participate due to illness. This clearly reduced the interaction during the actual event, but there were several other benefits. Having to create a video presentation opened the experience to students that may not have normally considered working on a STEM related project (e.g., students interested in arts/humanities and multimedia technology). The video presentations can also be used post-EDC as a promotional/recruiting tool for the participating high schools and the university. Weighing the pros and cons of pre-recorded video presentations, post-pandemic EDCs will blend both pre-recorded and live aspects for the final competition and/or scoring.

Another lesson learned is the importance of post-event follow up. Given the varied methods used by teams for the kinematic calculations, it would be beneficial for the teams to have a post-event discussion of their solution techniques to maximize the learning experience. This would require ensuring the final event is not held too late in the semester so there is sufficient time to follow up with each team individually in-person or as groups in a virtual setting before classes end for the term.

The Likert scale questionnaire (Tables 5 and 8) for both EDCs suggests that the pandemic version of EDC is not effective in encouraging students to attend the Armstrong campus of Georgia Southern University. This is not completely surprising given the virtual nature of the events. In a non-pandemic situation, the students would at least have come to the campus for the final competition event, if not prior to the event to work on the project. Campus tours could be incorporated into these campus visits. For example, the teams could be invited on campus to collect their 3D prints and then given a tour of the campus. Expanded resource (time) allocation should be carefully considered if these tours are faculty-led.

Conclusion

Two drone-themed virtual engineering design challenges were successfully held in 2020 and 2021. The original in-person EDC 2020 activities and event competition was canceled in Spring 2020 due to the COVID19 pandemic, but was restarted in Fall 2020 as a fully virtual event with three teams (12 students) participating. The teams designed and performed limited prototype testing of a grappling attachment for a drone. EDC 2021 was specifically organized as a set of hybrid activities and a virtual final event with five teams (27 students) participating. The teams designed and tested a lunar soil excavation device attached to a drone. They also performed kinematic analysis of drone flight. For both events, the majority of students showed a post-test score increase (not statistically significant in 2020, but was statistically significant in 2021). The majority of students in both events also indicated that EDC increased their desire to pursue a Science, Technology, Engineering or Math (STEM) career at a statistically significant level. The events were not as successful at encouraging students to consider attending the Armstrong campus of Georgia Southern University. This was not surprising due to both events being fully virtual and not having any physical connection to the university campus. The challenge of Engineering Design Challenges during a pandemic has demonstrated that the following should be continued in post-pandemic challenges: the use of virtual meetings to allow for easier and increased contact between the teams, coaches and mentors; requiring teams to create a project related video which can encourage more diversity in the team rosters, provide greater exposure to various multimedia presentation modalities, and organically builds STEM related content for future recruiting purposes. This experience has also reinforced the importance of in-person, on campus experiences as part of future EDC's to improve the connection between the participants and the university.

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Appendix A: EDC 2020: Pre/Post-Test

1. A/An _________________ is an aerial vehicle that can be piloted remotely or in some cases can be piloted autonomously. Autonomously means it can fly itself without the help of a human pilot. *

Mark only one oval.

- A) Unmanned Aerial Vehicle (UAV)
- B) drone
- C) quadcopter
- D) choices A, B and C
- E) none of the provided answer choices

2. EDC Eagle-ROAR was partly inspired by______________________ *

Mark only one oval.

- A) the 2018 EDC competition
- B) NASA's Mars 2020 rover mission.
- C) the recent SpaceX Dragon's launch escape demonstration
- D) the 2016 EDC competition
- E) none of the provided answer choices

3. When the lift force is equal to the drone's weight, the drone will hover or float in the air. This can be considered a/an *

Mark only one oval.

- A) balanced force system
- B) two force system
- C) frictionless system
- D) gravitational force system
- E) none of the provided answer choices

4. A quadcopter's propellers (also known as rotors) *

Mark only one oval.

- A) all spin in a clockwise direction
- B) all spin in a counterclockwise direction
- C) do not all have to spin at the same time
- D) must always spin at the same speed.
- E) none of the provided answer choices

5. The lift force created by the propellers (rotors) of a drone are also known as a *

Mark only one oval.

- A) friction force
- B) weight force
- C) thrust force
- D) drag force
- E) none of the provided answer choices

6. A pitch rotation of a drone causes the drone to move *

Mark only one oval.

- A) forward
- B) backward
- C) sideways
- D) Either A or B
- E) none of the provided answer choices

7. The ___________ is the brain of the drone, responsible for converting input from the receiver, the GPS Module, the battery monitor and the onboard sensors, to move the drone based on pilot commands *

Mark only one oval.

- A) electronic speed controller
- B) flight controller
- C) transmitter
- D) brushless motors
- E) none of the provided answer choices

8. A twisting motion of a drone is also considered a _____________ rotation. *

Mark only one oval.

- A) pitch
- B) yaw
- C) roll
- D) hybrid
- E) none of the provided answer choices

9. What are the units used to quantify the force due to gravity? *

Mark only one oval.

- A) mole
- B) Newton
- C) angstrom
- D) coulomb
- E) none of the provided answer choices

10. Why does the EDC: Eagle-ROAR competition require you to fly your drone indoors only? *

Mark only one oval.

- A) because it is more fun to fly indoors
- B) because it is harder to fly outdoors
- C) because of FAA drone registration requirements to fly outdoors
- D) because it will be easier for the drone to pick up payloads indoors
- E) none of the provided answer choices

Appendix B: Presentation Details (PD) for EDC2020:

The following is a list of details that should be included in your presentation.

1. PD1: What was the motivation for a drone themed EDC?
2. PD2: How do drones generate lift?
3. PD3: Why do drones use 4 rotors instead of 3? Do the rotors spin in the same direction? Why/Why not?
4. PD4: Describe the grappling design process
    a. Talk about the steps you took to develop your ideas and design.
    b. Show off any sketches of the designs you develop during brainstorming sessions.
    c. Did you build any prototype designs? What did you learn from them?
    d. Show images of the CAD model of your grappling design.
    e. What is the cost of your grappling design?
5. PD5: Describe your hanger payload design process and your final design plan. It is ok if this is still a work in progress since teams are not likely to meet face to face.
6. PD6: Share what you learned from this project.

Appendix C: EDC 2021: Pre/Post-Test

A key goal of the NASA Artemis mission is to *

Mark only one oval.

- land the first humans on the Moon
- land the first woman on the Moon
- use drones to explore the Moon for water
- land the first humans on Mars
- none of the provided answer choices

What is the average acceleration of a drone If it takes off from rest and reaches a velocity of 6 m/s (meters per second) in 3 seconds. Recall that the units of acceleration are m/s^2. *

Mark only one oval.

- -2 m/s^2
- 2 m/s
- 0.5 m/s^2
- 2 m/s^2
- none of the provided answer choices

During the vertical takeoff of a drone, the thrust force is *

Mark only one oval.

- equal to the weight of the drone
- equal to the mass of the drone
- greater than the weight of the drone
- less than the weight of the drone
- none of the provided answer choices

If a drone takes 5 seconds to travel between two fence posts that are spaced 10 meters apart, what is the average speed of the drone? *

Mark only one oval.

- 0.5 mph
- 2 mph
- 10 m/s
- 5 m/s
- none of the provided answer choices

If the weight of a drone is 9.81 N and the acceleration due to gravity is 9.81 m/s^2, the mass of the drone is *

Mark only one oval.

- 1 kg
- 9.81 N
- 1 lb
- always greater than the weight of the drone
- can sometimes be equal to the weight of the drone

Newton's _____ Law relates the total force acting on an object to the object's mass and acceleration *

Mark only one oval.

- 1st
- 2nd
- 3rd
- Gravitational
- none of the provided answer choices

When a drone pitches forward, ____________ of the thrust force acts in the horizontal direction to accelerate the drone horizontally. *

Mark only one oval.

- a component
- the velocity
- the acceleration
- a newton
- none of the provided answer choices

A twisting motion of a drone is also considered a ____________ rotation. *

Mark only one oval.

- pitch
- roll
- yawl
- hybrid
- none of the provided answer choices

What are the units used to quantify the mass of an object *

Mark only one oval.

- newton
- pound-force
- g's
- kilogram
- kilonewton

Why does the EDC: Eagle-ROAR2 competition require you to fly your drone indoors only? *

Mark only one oval.

- because it is more fun to fly indoors
- because it is harder to fly outdoors
- because of FAA drone registration requirements to fly outdoors
- because it will be easier for the drone to pick up lunar soil indoors
- none of the provided answer choices

Appendix D: Presentation Details (PD) for EDC2021:

The following is a list of details that should be included in your presentation.

1. Brief details of the Artemis mission and motivation of EDC 2021- Eagle ROAR 2.0.
2. Your excavation attachment design process, including an explanation of if/how the size of the excavation tool affects how quickly your loaded drone can transport soil (Hint: amount of soil carried vs. drone's velocity).
3. Highlight the performance of the excavation system from the 2 attempts previously recorded and supplied to the team.
4. Discussion of the feasibility of using a propeller based drone on the moon.
5. Based on this downloadable video clip of the drone flying, calculate and discuss the following:
    a. Plot the horizontal velocity (in units of meters/second - m/s) of the drone with respect to time (in units of seconds - s) based on the blue tape marks and frame rate. Using this velocity with respect to time plot, determine the average horizontal acceleration (in units of meters/second^2 - m/s^2) over the same time interval.
    b. Based on the pitch angle of the drone in the video, determine the expected horizontal acceleration (m/s^2) and compare that to the horizontal acceleration (m/s^2) calculated above. Discuss any discrepancies between the two values. The pitch angle should be measured from a vertical axis.
    c. Assume the following for your analysis:
        i. The blue tape marks in the video are spaced 0.1524m (6 inches) from centerline to centerline.
        ii. The video is recorded at 30 frames/sec.
        iii. Assume the video camera is far enough away that this can be treated as 2-D motion.
        iv. The drone has a mass of 0.582 kg.
        v. Discuss any other assumptions you made for your analysis.