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Design and Implementation of Virtual Research Projects in Aerospace Engineering through a Virtual Summer Research Program

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Abstract

With the booming SpaceX in Boca Chica and other aerospace companies in the region, South Texas has a strong and fast-growing need for a qualified workforce in aerospace engineering despite COVID-19 concerns and is becoming the next Cape Canaveral of the 21st century. However, there is no community college or 4-yr university in South Texas offering an aerospace engineering undergraduate or graduate program. To promote aerospace engineering and increase students' interest in aerospace engineering in South Texas, Texas A&M University-Kingsville offered a three-week virtual summer research program in Summer 2021 focusing on aerospace engineering. The virtual setting of the summer research program allows reaching out to much larger student populations in South Texas including those who cannot commute or cannot attend in-person due to part-time jobs or other responsibilities related to their families. Nineteen students from different STEM majors were recruited from both community colleges and 4-yr universities, including 16 Hispanic students. The students were divided into four teams. Each team worked together to complete a research project in three weeks with the guidance of a faculty member and a graduate student. Each team met at least once a day and completed two progress presentations, one final project presentation, and a written project report. In addition, webinars and professional development training were also provided during the three weeks. The topics of the four research projects are 1) Airworthiness and System Safety, 2) Distributed Propulsion/Engine Vehicle Concepts, 3) Computer Simulation of Aerospace Systems with Animation, and 4) Re-design of UAV Airplane to Fly on Mars. The paper discusses the detailed design of the 3-week virtual research program. It also describes the design of the four research projects. A post-survey was conducted to collect students' feedback on the program and the research projects. The results of the survey and the impact of the program and the research projects on students' interests and knowledge in aerospace engineering are discussed. The challenges and experiences are also discussed, including the preparation of students from different backgrounds and possible distractions of the virtual environment.

Introduction

According to the 2019 National Survey of College Graduates sponsored by NSF [1], a large and increasing number of US college graduates with bachelor's degrees have attended community colleges. About 52% of the 14.8 million graduates, who earned their first bachelor's degree between 2008 and 2017, had previously attended a community college while 25% had earned an associate's degree. In contrast, among the 29.8 million college graduates who earned their first bachelor's degree before 2008, only 48% had attended a community college and only 19% had earned an associate's degree. In addition, underrepresented minorities (URMs) were more likely than Whites to have attended community colleges (57% of Hispanics versus 47% of Whites) and to have earned an associate's degree (approximately 26% of Hispanics versus 20% of Whites).

South Texas, though rich in natural resources and economic growth opportunities, remains historically underserved and economically disadvantaged with a majority (>68%) Hispanic population [2]. Considering a large number of low-income and first-generation college students in South Texas, community colleges are very attractive to high school students due to their low tuition and close distance.

Program Design

There is minimal local internship opportunity in STEM fields in rural South Texas towns. Few STEM students get the opportunity to experience a true work environment before being thrust into the workforce after graduation. A three-week virtual summer research internship (SRI) program was offered in Summer 2021 to students at Texas A&M University-Kingsville and its nearby universities and community colleges. The SRI program is designed as a mini-internship to provide academic, professional, and career preparation to SRI participants. A total of 19 students were selected as SRI participants in Summer 2021, who were divided into four teams. Four graduate students with research experience were selected as "SRI fellows" in the SRI program to assist faculty advisors to provide research and career guidance to SRI participants. So, each team comprised five SRI participants, one SRI fellow, and one faculty advisor. Table 1 shows the demographic information of the 19 SRI participants.

Table 1: Demographic Information of Summer 2021 SRI Participants

# of male students	8
# of female students	10
# of Hispanic or Latino	16
# of students from 4-year universities	10
# of students from community colleges	9

The SRI interns work together in a team setting to complete the research internship projects with guidance from faculty advisors and SRI fellows. Each team was required to prepare weekly progress reports, a final poster and oral presentation, and a final project report. Industrial professionals were invited to offer weekly webinars during the SRI program. In addition, SRI participants were required to complete personal financial literacy and professional development trainings with the program coordinator to prepare themselves for future internships and STEM careers. The financial literacy training was conducted using the iGrad platform [3], while the professional development training was conducted using Explore Your Potential (EYP) platform [4]. Table 2 shows the daily activities and schedule of the SRI program.

Table 2: Daily Activities and Schedule of the SRI Program

Week	Day 1	Day 2	Day 3	Day 4	Day 5
W1	• Orientation • Research training		• Weekly webinar		• Friday Progress Presentation with all the teams (5 minutes presentation summarizing the weekly progress)
	• Conduct research activities through daily virtual meetings with faculty, graduate students, and team members • Financial Literacy Training (self-paced in the iGrad platform) • Professional Development Training using the EYP platform (half an hour virtual meeting with the program manager)				
W2			• Weekly webinar		• Friday Progress Presentation with all the teams (5 minutes presentation summarizing the weekly progress)
	• Conduct research activities through daily virtual meetings with faculty, graduate students, and team members • Financial Literacy Training (self-paced in the iGrad platform) • Professional Development Training using the EYP platform (half an hour virtual meeting with the program manager)				
W3			• Weekly webinar		• Final Project Presentation (8 minutes presentation summarizing the research results)
	• Conduct research activities through daily virtual meetings with faculty, graduate students, and team members • Prepare and complete final project presentation and report • Financial Literacy Training (self-paced in the iGrad platform) • Professional Development Training using the EYP platform (half an hour virtual meeting with the program manager)				

Design of the Virtual Research Projects

Four different research projects were completed virtually in Summer 2021. In order to complete the SRI projects in three weeks, the SRI research projects were chosen from Aerospace Engineering related senior design projects and other research projects conducted at Texas A&M University-Kingsville and further modified by SRI faculty advisors.

Project #1: Airworthiness and System Safety. Airworthiness is the status of an aircraft, engine, propeller, or part when it conforms to its approved design and is in a condition for safe operation. System safety approaches can be used to evaluate and analyze any product or system in risk management to reduce the accident or failure probability. In this project, students learned what airworthiness is and how system safety approaches could be applied to airworthiness evaluation and improvement. In the first week of the project, risk management methodologies such as Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) [5], [6] were introduced to students. Students were also asked to perform a literature review on airworthiness to gain knowledge of the current research on aircraft safety issues. Students investigated the database and incident report from the FAA website. During the second week, students identified the research problem for the group and each individual research objective. Each student was asked to select one incident from the FAA website to conduct a deep investigation and use at least two system safety methodologies in the analysis. Once each student completed their individual research, the group worked together to conclude the project with recommendations on airworthiness improvement and incident prevention. Figure 1 shows an example of the students' results.

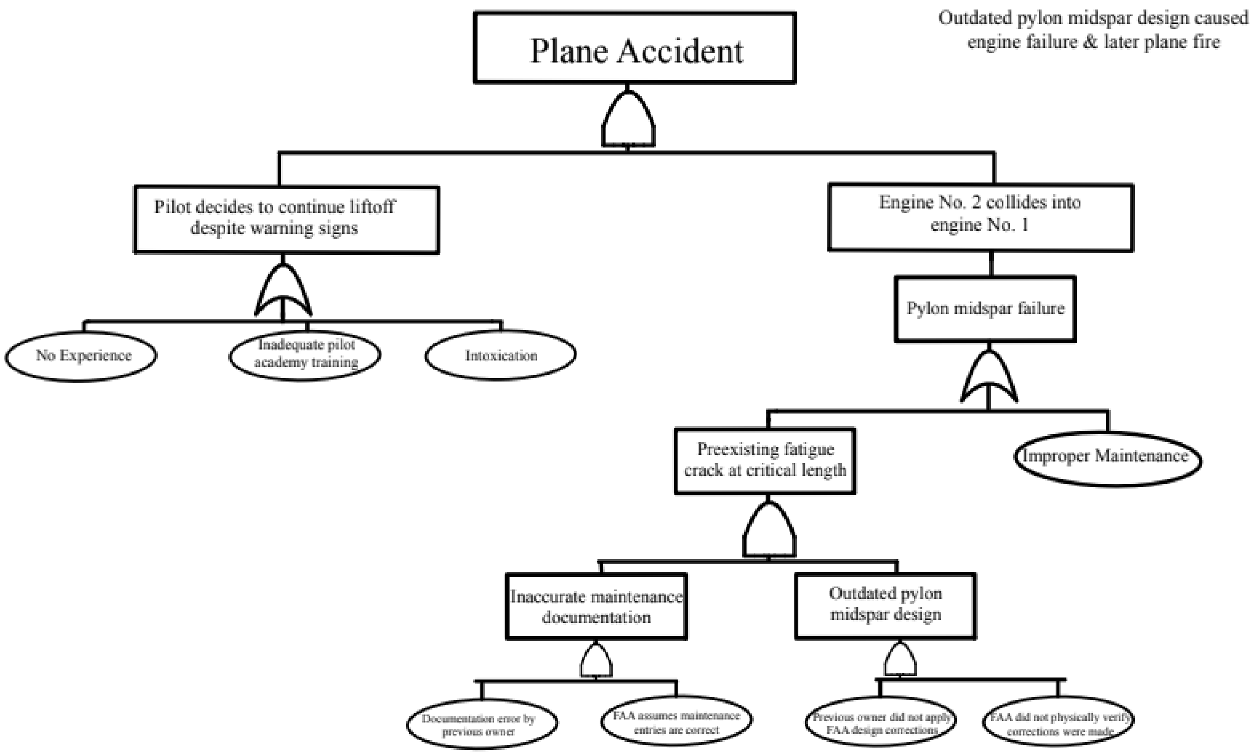

Figure 1: Sample results from Project #1, Pylon Midspar Failure Boeing 707, N707AR – FTA

Project #2: Distributed Propulsion/Engine Vehicle Concepts. In this project, the SRI participants designed an equivalent distributed propulsion system for a typical commercial airplane. Distributed propulsion in aircraft application is the spanwise distribution of the propulsive thrust stream such that overall vehicle benefits in terms of aerodynamic, propulsive, structural, and/or other efficiencies are mutually maximized to enhance the vehicle mission. Distributed small multiple engines located along the spanwise direction of wings is one of the examples. A commercial passenger airplane model Boeing 777 had been selected to investigate the effects of an equivalent distributed propulsion system. The Boeing 777 airplane model with four and eight combinations of distributed propulsion has been designed and simulated to study the flow field and vortex distributions. A well-known computer-aided drafting and design (CAD) software named SolidWorks is utilized for the design and subsequent simulation of the flow field around the aircraft models. The results of flow simulations have been compared with the conventional airplane model. It has been found that the turbulence wake was complex for the distributed propulsion system as compared to the conventional airplane model. Moreover, the complexity of the wake increased with the increase in the number of turbojet engines. Figure 2 shows an example of the students' results.

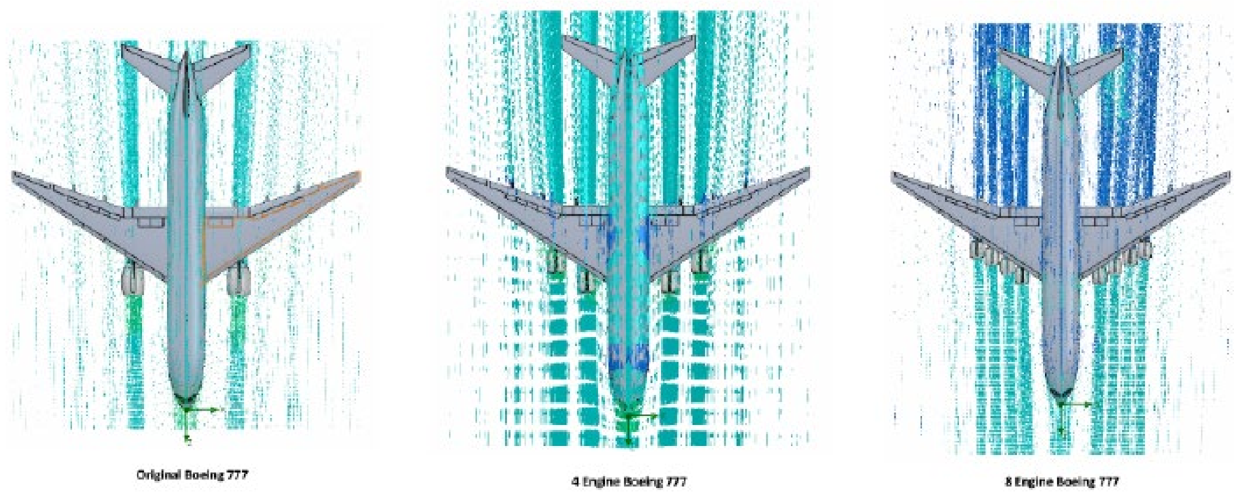

Figure 2: Sample results from Project #2, simulation results of an airplane with different numbers of engines.

Project #3: Computer Simulation of Aerospace Systems with Animation. This project focused on using ARENA, a computer simulation software, to develop simplified simulation models with animation of real aerospace systems or processes. The students worked closely with a faculty and a graduate student in a daily basis during the three weeks. In the first week, the students spent the majority of their time 1) understanding basic concepts of computer simulation and probability distribution, 2) learning basic operation and modeling of ARENA software, and 3) choosing an appropriate aerospace system or process for simulation. In the second week, the students started to collect the necessary data for their selected system or process, create simplified ARENA simulation models of the selected systems or processes, and learn to add animation to ARENA simulation models. In the last week, the students input the processed data into the ARENA simulation model and added animation for visualization purposes in the model. One student selected rocket launching processes, while the other four students selected different airport operation processes, including security checks, flight schedules under extreme weather conditions, flight take-off and landing with emergent conditions, and aircraft maintenance. Through this three-week project, the students were able to 1) understand the concepts and importance of computer simulation, 2) learn to use ARENA simulation software to develop simple simulation models with animation, and 3) collect, process, and analyze real-world data from various sources. Figure 3 shows an example of the students' results.

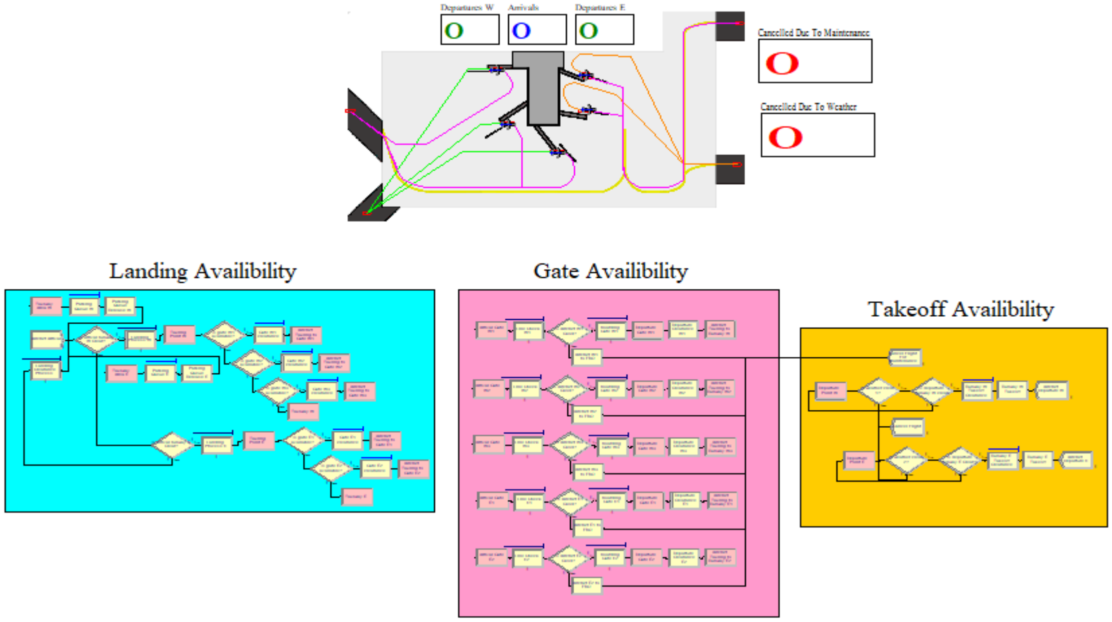

Figure 3: Sample results from Project #3, simulation results of a small airport's operations with Arena models.

Project #4: Redesign of a Fixed-Wing UAV to fly on Mars. With the success of NASA's helicopter flying on Mars, a project was developed to conduct the basic redesign of a fixed-wing UAV (airplane) so it could fly on Mars. This was facilitated by the use of a browser-based software package from NASA, called FOILSIM III, which could be reconfigured with atmospheric data on Mars. The 5 undergraduate students, graduate mentor, and faculty advisor met remotely, on a daily basis, to complete the project. The first week consisted of an introduction to important concepts of aerodynamics such as lift force, drag force, and coefficients of lift and drag. Along with studying those concepts, the team gathered information about Earth and Mars and constructed spreadsheets in Excel to compare their differences. During the first week, the team also researched the characteristics of several different electric-powered UAVs, then organized that data to help decide which UAV would be re-designed. In week two, the team refined the data on the spreadsheets as well as the UAV's characteristics, then began evaluating that information through an online FOILSIM III software provided by NASA. FOILSIM calculated the lift/drag force and lift/drag coefficients based on the airfoil and other parameters of the UAV. The group studied how modifications to the wing structure, angle of attack, velocity, etc., influenced the performance. During the third week, the team determined exactly what changes needed to be made to the UAV and conducted the redesign of the UAV using SolidWorks and Fusion360 CAD software. To make the electric UAV fly on Mars, its wingspan had to be increased from 1.5 m to 3.8 m, yet weight needed to be reduced, so its rather bulky fuselage was reduced in volume by 2/3rd, and a light-weight carbon fiber/epoxy composite was used for all structural components. The current electric motor and batteries seemed to provide sufficient power. During this 3-week project, the students were able to a) learn and understand the basic aerodynamic theory, b) learn the differences between Earth's and Mar's atmosphere, develop & use Excel spreadsheets, and use the FOILSIM III software. c) They evaluated trade-offs between gross weight, take-off speeds, air density, wing area, and so on. d) They gained time-management, communication, and teaming skills, as they worked to accomplish their project in a short period of time while possessing a wide variety of skills, and local internet and computing resources. Figure 4 shows an example of the students' results.

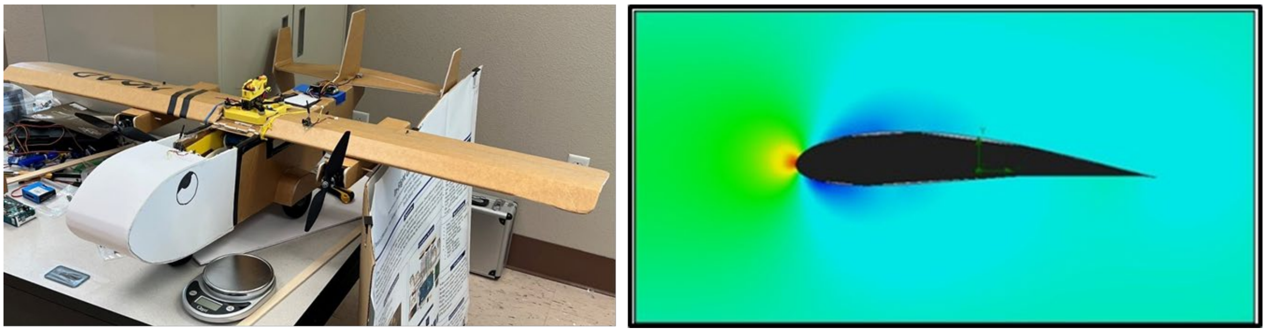

Figure 4: Sample results from Project #4, physical model, and simulation results.

Program Assessment Results

A total of 13 participants in the three-week summer program accessed the post-participation survey. One stopped supplying responses after completing the demographic queries. The information gathered from the 13 informants confirms that they were representative of the cohort as the proportion of individuals in key demographic categories were similar.

- The cohort had eight males, 10 females, and one undeclared party while survey respondents were five males and eight females.
- The cohort includes 16 persons who identified as Hispanic/Latinx and three who did not categorize themselves while the survey respondents were 11 Hispanic/Latinx individuals and two non-Hispanics. All of the students who identified as Hispanic considered their racial category to be Hispanic/Latino while the two non-Hispanics identified as Asian.
- Ten of the cohort members attend four-year institutions and nine were community college students while the survey informants were seven students at four-year schools and six from community colleges.

An item included in the survey indicates that many of the respondents from community colleges anticipated transferring to a four-year college or university to complete an undergraduate degree. Five of the six informants from community colleges noted they planned to transfer to another school to complete an undergraduate degree in a STEM field (one party did not respond).

A sample of 13 parties for demographics and 12 for all other queries is too small to support meaningful statistical analysis as subsets created through disaggregation would be too small, as few are two or three individuals. The only comparison possible was responses from males and females which produced no significant results. Yet, the sample has the desirable characteristic of being representative. Thus, the trends seen in the data, while only suggestive, can, as a result, be generalized to the entire group. Table 3 contains the survey prompts and mean, mode, and standard deviation for each query.

Table 3: 2022 Student Ratings of Three-Week Summer Research Programming

Prompt	Mean	Mode	SD
Overall rating of the three-week, online summer program.	9.33	10	1.18
What percentage of information in the three-week online summer research program was new to you?	73.58%	70.0%	17.58
I would like to learn more about the topic covered in the three-week online summer research program.	4.5	5	0.65
I would recommend the three-week online summer research program to other students.	4.67	5	0.62
The information shared was of interest to me.	9	10	1.35
I can see how the information shared in the summer research program is applicable in aerospace engineering.	9	10	0.87
I can apply the information shared in the summer program in science, tech, math or engineering settings.	8.92	10	1.19
I learned about designing and conducting experiments.	7.75	10	2.83
I learned about analyzing and interpreting data.	8.17	10	2.15
I learned about designing a component, system, or process.	8.27	10	1.91
My experiences in the program made me more confident I can work on a multi-disciplinary team.	8.50	10	2.18
I learned about identifying, formulating, and solving engineering problems.	8.17	10	2.30
I learned about engineering ethics.	7.42	10	3.20
I learned about engineering's impact on the economy, ecology, and society(ies).	7.33	10	3.52
The material discussed was relevant to the present day.	9.0	10	1.87
The activity made me more interested in completing a science, tech, math and/or engineering major or minor.	8.58	10	2.78
The activity made me more interested in majoring or minoring in aerospace engineering.	7.75	10	2.38
The activity made me more interested in pursuing a career in science, tech, math and/or engineering.	8.58	10	2.40
The activity made me more interested in pursuing a career in aerospace engineering.	7.67	10	2.21

Several scales were employed in the survey. The questions about wishing to learn more about the topic of the program and recommending the opportunity to others employed a traditional five-point Likert scale. The query about the percentage of information that was new to the student employed a 100-point scale. All other questions had ten-point rating scales.

Conclusion

With 12 informants reporting their perspective of the same programming, it is not advisable to assign substantial interpretative weight to the survey outcomes as each party's opinion makes up too large a portion of the result (~8.33%). Several students submitting low ratings for an element that their peers rated much higher, a circumstance that did occur, would depress the mean and increase the standard deviation substantially. Thus, trends in the data can only be seen as tentative patterns based on one small and initial sample. Even with that caveat, there are several notable trends.

- The three-week summer research program received consistently high ratings from participants with all informants willing to recommend participation to their peers.
- Much of the information, up to as much as 100% for two informants, was new to the students.
- The activity stimulated interest in, in decreasing order of magnitude, learning more about the topic, a minor/major and career in STEM (same means), a minor/major in aerospace engineering, and a career in aerospace engineering.
- Participants considered the material interesting and relevant to the present day.
- Learning was reported in six key areas: (a) designing and conducting experiments, (b) analyzing and interpreting data, (c) designing a component, system or process, (d) identifying, formulating and solving engineering problems, (e) engineering ethics, and (f) engineering's impact on the economy, ecology and society(ies).
- An increase in confidence in student ability to function on multi-disciplinary teams.
- There were no significant differences between the responses submitted by persons identifying as male and female.

These are positive outcomes for a project focused on broadening participation in aerospace STEM education and the aerospace workforce while identifying and understanding the factors that motivate students from underrepresented groups, especially Hispanics and females, in order to guide their interest and persistence in aerospace-related STEM majors. Yet, they existed for one group of students. The outcomes must be replicated with one or more subsequent groups of participants in order for these trends to be considered to be a stable outcome of the programming.

Acknowledgments

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