Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #48010

BOARD # 15: From Drones to Airplanes – Lessons Learned from Uncrewed Aviation for Teaching Innovative and Sustainable Electric Aviation Propulsion

Prof. Christian . Janke ., Embry-Riddle Aeronautical University - Worldwide

Christian Janke is an Assistant Professor at Embry Riddle Aeronautical Universities Worldwide Campus and the Associate Program Chair for the Bachelor of Science in Unmanned Systems Applications. He teaches at degree programs involving Unmanned Systems.

Dr. Yuetong Lin, Embry-Riddle Aeronautical University - Worldwide

Yuetong Lin received the Ph.D. degree in Systems and Industrial Engineering from the University of Arizona, Tucson, in 2005. He was with Indiana State University from 2005 to 2016, where he became associate professor of Electronics and Computer Engineering Technology. He joined Embry-Riddle Aeronautical University Worldwide in 2016 as an associate professor in the School of Engineering (formerly Department of Engineering and Technology).

Dr. Ghazal Barari, Embry-Riddle Aeronautical University

Dr. Ghazal Barari received her Ph.D. in Mechanical Engineering from the University of Central Florida, where her research focused on combustion modeling of promising biofuels to identify suitable alternatives to fossil fuels. She began her academic career as a tenure-track faculty member at Embry-Riddle Aeronautical University and has since expanded her research to include engineering education, with a focus on developing innovative virtual labs, active learning strategies, and simulation tools to enhance student engagement and learning in online environments.

From Drones to Airplane – Lessons Learned from Uncrewed Aviation for Teaching Innovative and Sustainable Electric Aviation Propulsion

Abstract

The adoption of electric propulsion in aviation is poised to significantly impact aerospace education and influence recruitment, student retention, and technical training in aerospace and aeronautics programs. Electric propulsion requires knowledge from various disciplines such as electrical engineering, materials science, and computer science. This interdisciplinary nature appeals to a wider range of students and offers diverse challenges. In this work-in-progress paper, we present a case study of teaching the subject in the online environment. We highlight the need for new technologies, faculty development, and how programs and degrees must adapt to create the future of aerospace education, drawing on the lessons learned from our experience.

Introduction

The transition from traditional aviation and aerospace to electric propulsion is driven by a convergence of technological advancements, environmental imperatives, economic incentives, and regulatory pressures. Electric propulsion systems, which rely on high-efficiency electric motors and advancements in battery technology, offer significant advantages over conventional combustion engines that rely on fossil fuels. Chief among these is the potential to drastically reduce carbon emissions and local air pollutants, addressing the aviation sector's contribution to climate change and improving air quality in urban and airport-adjacent areas. Additionally, the quieter operation of electric motors makes them particularly suited for urban air mobility solutions and noise-sensitive environments. From an economic perspective, electric propulsion promises lower operational costs due to reduced fuel consumption and maintenance needs, while also mitigating the industry's reliance on volatile fossil fuel markets. Regulatory frameworks, such as stricter emissions standards imposed by international bodies such as the International Civil Aviation Organization (ICAO), further incentivize this transition, as does the growing consumer demand for sustainable aviation solutions.

Online education has witnessed remarkable growth in the past decade, especially in the U.S. According to a report from the U. S. Education Department's National Center for Education Statistics [8], there was a substantial 5.7% increase in the number and proportion of college and university students enrolled in online classes in 2017. This growth persisted even as overall post-secondary enrollments experienced a slight decline of 0.5%. The global COVID-19 pandemic, spanning from 2020 to 2023, propelled the adoption of online education to unprecedented levels. Initially implemented as an emergency measure to address school closures, online modality has since been embraced by numerous higher education institutions due to its inherent advantages [1, 13], which include enhanced flexibility, increased interactivity, and the ability for students to pace their own learning.

Historically, online engineering programs have faced skepticism, particularly due to concerns over the lack of hands-on lab experiences. There has been a strong belief that students must physically engage with real machines, equipment, and circuits that closely mirror those used in real-world applications—something simulations alone cannot fully replicate. Fortunately, advancements in technology have significantly addressed this concern. Affordable, portable, and functionally capable educational equipment is now widely available, enabling students to set up home labs and gain practical experience. Devices like drones, for example, are not only budget-friendly but also offer performance comparable to what students might encounter in centralized labs or field settings. This evolution has played a key role in supporting the growth and credibility of online engineering programs.

The growth of online engineering education has been recognized by accreditation agencies, with the number of ABET-accredited 100% online engineering programs rising to 34 in the latest count. Although, to the best of our knowledge, ABET has not accredited any online undergraduate aerospace engineering programs, the potential and feasibility of online aeronautics and aviation education have been acknowledged by other leading accreditation bodies. For instance, the Royal Aeronautical Society—one of the premier professional organizations dedicated to aerospace and aviation—has approved both bachelor’s and master’s online aviation degrees, including those offered at Embry-Riddle Aeronautical University Worldwide (ERAU-W). This highlights the growing acceptance of high-quality online programs in the field.

The transition to online education necessitates a collaborative and concerted effort from various academic and administrative units. At the core of every well-established online program is the curriculum that must maintain the required academic rigor while address the unique challenges facing both instructors and students in this new learning environment. These challenges include developing “time management skills, being technologically prepared and computer literate, possessing good work ethics, being effective communicators and goal-oriented learners, ensuring academic readiness, and fostering personal commitment, independence, and responsibility” [13].

Embry-Riddle Aeronautical University Worldwide is one of the leading online universities in the country and had been ranked consistently either No. 1 or No. 2 among all institutions, private or public, in the annual U. S. News and World Report from 2016 to 2023. Beginning as a school that offered distance education primarily to active service members and veterans, ERAU-W was among the first universities to recognize the potential of, and thus shift to online education. Students can choose from a variety of aviation and aerospace-oriented academic and professional programs, both at the graduate and undergraduate levels, that teach novel and emerging technologies and trends, such as uncrewed systems, cybersecurity, and sustainability.

Electric drivetrains and batteries are not completely new to all three segments of General Aviation, Business Aviation and Commercial Aviation in the traditional aviation. It has played a transformative role in the development over the past century, enabling advancements in navigation, communication, propulsion, and onboard systems. Early electrical systems in aircraft primarily powered essential navigation and communication instruments, such as radios and basic flight gauges, which enhanced pilot situational awareness and operational safety. Over time, the scope of electrical integration expanded significantly with the advent of more sophisticated avionics, including autopilot systems, radar technology, and digital flight control systems, which relied heavily on electrical power for precision and reliability. Electrical systems also revolutionized cabin environments, providing lighting, heating, and entertainment systems that improved passenger comfort.

Furthermore, the gradual transition from mechanical to electrically actuated components, such as flaps and landing gear, reduced aircraft weight and maintenance complexity. This evolution laid the groundwork for modern aircraft systems and influenced also the training of personnel working in manufacturing and maintaining aircraft platforms and components. Hence, a small amount of training content for technical personnel included elements of electric components [18]. However, such material has yet to be widely integrated into college curricula.

In this work-in-progress paper, we present a case study of teaching the concept of electric propulsion in aviation with drones or CAD in the online environment. We highlight the need for new technologies, faculty development, and how programs and degrees must adapt to create the future of aerospace education, drawing from the lessons learned from our experience.

Status-Quo of Curriculum Development for Electric Propulsion

The growing interest in electric propulsion has spurred significant advancements in research and professional training. For example, component-level technologies required for enabling electric drivetrains are being assessed by both industry and academia, with increasing levels of activity in the past decade being discussed in [19]. Sahoo, Zhao, and Kyprianidis surveyed the current landscape of research endeavors and the formulated derivations related to electric aircraft developments. The barriers and the needed future technological development paths are discussed. The paper also includes detailed assessments of the implications and other needs pertaining to future technology, regulation, certification, and infrastructure developments, in order to make the next generation electric aircraft operation commercially worthy.

However, given the relatively new nature of this technology, discussions on effectively integrating the concepts and practices of electric propulsion into undergraduate curricula are still in their early stages. Very few programs have developed mature electric propulsion content. Several papers reported the plan to include electric propulsion component in maritime powertrain. For example, the development of a job-training course model on electric propulsion ships was introduced in [10], where the practical training consists of contents to assist the understanding of the electric propulsion system, and practice the measures necessary for the maintenance and management of the ship, and the theoretical training to cover subjects that include characteristics of propulsion motors, converter systems, inverter systems, cooling systems, work safety procedures, and safety devices. Kulatunga and Wijenake discussed different paths in a program curriculum to introduce skills for electric Powertrain in marine propulsion. On the other hand, there are even less references on curriculum development for electric propulsion in aircraft.

Yother and Johnson discussed how to build the foundation to introduce new battery technology in aviation applications, and in [20], Yother and Johnson examined the identification of student outcomes for electric propulsion aircraft based on industry-developed consensus standards.

We believe there are two main reasons for the lack of progress. The relatively new nature of electric propulsion technology means there is no established consensus on the subjects that should be included in a curriculum, creating challenges in standardizing its education. Additionally, the credit hour limits of engineering degree programs make it difficult to introduce new courses without displacing existing content. In traditional brick-and-mortar institutions, even when a suitable subject is identified, maintaining consistency across instructors and ensuring up-to-date teaching materials can be challenging. Online learning, however, offers significant advantages in this regard. Through the use of a master course template, all instructors teaching the course follow a unified structure, ensuring consistency in content delivery. These templates are regularly updated to include new materials, reflecting advancements in the field, and course modules can be easily expanded or modified to adapt to emerging educational needs. It is important to note that learning management systems, such as Instructure Canvas, also provide standardization and harmonization opportunities for in-person classroom teaching, allowing instructors to use the same online lesson templates.

Electric Propulsion Revolution within the Aviation Sector

Fard et al. reviewed the state-of-the-art advancements in aircraft electrification. Three major Distributed Electric Propulsion(DEP) categories, i.e., turboelectric, hybrid-electric, and all-electric propulsion technologies, are investigated. Although all of them utilize electric fans as propulsors, their system structures and power generation stages are different. Hence, comprehensive considerations are required to optimize the DEP system designs. Starting with the multifarious electrical system architectures proposed in the literature, a thorough review is conducted including the system parametric specifications, design considerations of power converters, the power electronics devices' characteristics in cryogenic conditions, and various energy storage systems. This review aims to provide a reference to researchers, engineers, and policy-makers in aviation to accelerate the progress toward future net-zero emissions.

In [14], current landscape of research endeavors and the formulated derivations related to electric aircraft developments was discussed. The barriers and the needed future technological development paths are discussed. The paper also includes detailed assessments of the implications and other needs pertaining to future technology, regulation, certification, and infrastructure developments, in order to make the next generation electric aircraft operation commercially worthy.

While applications of electric propulsion are currently most viable for short-haul and regional aviation, as well as urban air mobility via electric vertical take-off and landing (eVTOL) aircraft, ongoing advancements in energy storage and motor technologies suggest eventual scalability to long-haul flights and larger aircraft. However, challenges such as the relatively low energy density of batteries compared to jet fuel, the need for significant infrastructure upgrades, and the technical complexity of adapting electric propulsion to large aircraft remain barriers to widespread adoption. Despite these challenges, the industry's clear trajectory toward electric propulsion reflects its commitment to achieving environmental sustainability, economic efficiency, and technological innovation.

Technological innovations are central to this transformation, with companies developing eVTOL aircraft to revolutionize urban mobility. For instance, Joby Aviation's hydrogen-electric air taxi has achieved a record 523-mile flight, demonstrating the potential for efficient, zero-emission urban transportation [7]. Similarly, British start-up Vertical Aerospace is progressing towards commercial production of electric flying taxis by 2027, despite challenges such as the withdrawal of key partners [12].

Figure 1 visualizes several platform concepts with comparable electric propulsion and increasing complexity and associated regulation. All of them follow the same concept and layout, with different design and engineering requirements, rooting the basic knowledge of fixed-wing and multirotor UAS/drones.

Figure 1: Electric Drones and eVTOL

Impacts on Aviation and Aerospace Education and Training Requirements

There is a pressing need for the aviation sector to align education and training programs with the demands of electrification. This includes but is not limited to updates to education and training requirements, reflecting the shift towards electric propulsion systems and sustainable practices. This transformation demands a focus on advanced knowledge of high-voltage systems, energy storage, and battery management, as well as the integration of electric motors and power electronics into aircraft design and maintenance. Additionally, interdisciplinary understanding is critical, with curricula increasingly incorporating renewable energy sources, thermal management, and aerodynamics tailored to electric aviation [16]. Pilots and technicians must also adapt to new operational procedures and safety protocols specific to electric aircraft, including the management of charging infrastructure and handling of energy-dense materials [17]. Also other authorities highlight that workforce development must emphasize research and innovation skills to address the ongoing challenges of scalability and energy efficiency in electric aviation [4].

As basis for innovative electric propulsion concepts in the airspace sector, standards and regulations have been defined. The revised CS-23/Part 23 regulations—which govern the certification of small aircraft in the European Union (EASA) and the United States (FAA), respectively—emphasize performance-based, flexible standards rather than prescriptive rules. This shift enables greater innovation in aircraft design and certification while maintaining safety. It is expected that the educational requirements for professionals in this field also need to adapt to meet these new demands.

Drones as Innovative Educational Tool

Drones and Uncrewed aircraft systems (UAS) serve as an effective educational tool to teach students the principles of electrical engineering by providing a hands-on and interdisciplinary approach. Using drones as a teaching tool can make electrical engineering concepts tangible and engaging for students. These devices integrate key electrical engineering concepts, such as circuit design, power systems, motor control, and signal processing, into a tangible, real-world application. For instance, students can explore the intricacies of electrical circuits by assembling or troubleshooting a drone's circuit board, gaining a practical understanding of voltage, current, resistance, and power distribution.

Additionally, drones rely on advanced sensors like gyroscopes, accelerometers, and GPS, which enable students to study sensor functionality and signal processing in detail. The power systems of drones, typically battery-operated, allow students to analyze battery performance, capacity, and energy efficiency. Furthermore, the operation of brushless DC motors in drones introduces students to motor control concepts, such as pulse-width modulation and the role of electronic speed controllers. Building on the earlier discussion of the opportunities and challenges of online education in STEM and aviation/aerospace [9], small classroom drones can capitalize on benefits such as availability, flexibility, and usability. Whether in an in-person classroom or an online setting, small drones provide hands-on experiential learning opportunities.

Wireless communication technologies, including RF signals, Bluetooth, and Wi-Fi, provide a platform for learning about signal transmission and communication protocols. Drones also rely on embedded systems, offering opportunities for students to develop and implement programming solutions for navigation and control. The design and integration of printed circuit boards (PCBs) in drones introduce students to compact and efficient circuit design.

Additionally, drones present practical scenarios for troubleshooting and debugging, which are critical skills in electrical engineering. By engaging in projects that involve building, analyzing, or enhancing drones, students can connect theoretical knowledge to real-world applications, fostering a deeper understanding of electrical engineering concepts while inspiring innovation in related fields.

ERAU-W has extensively utilized UAS as educational tools to foster hands-on learning, research innovation, and interdisciplinary collaboration. Through specialized degree programs and curricula, students gain theoretical and practical knowledge in areas like system design, flight operations, and regulatory compliance. Figure 2 shows an example of an instructor introducing the nano drone in an online class setting. Several assignments and activities introduce the general concept of the Raspberry Pi and the nano drones as platforms and concepts. Figure 3 shows the course activities using the Python Integrated Development Environment (IDE) on the Raspberry Pi 400 connected to the nano drone.

Figure 2: Instructor Demonstrating Nano Drones in Online Video

Drones are also used in experiential learning environments, where students engage in real-world applications such as environmental monitoring, infrastructure inspection, and disaster response, reinforcing problem-solving skills and technical expertise [2]. Furthermore, UAS technology is integrated into research initiatives, enabling students and faculty to explore emerging fields such as autonomous systems, advanced data analytics, and artificial intelligence [15]. This approach ensures that graduates are well-prepared for the growing demands of the UAS industry, which has been identified as a critical area for workforce development [5].

Applicability and Suitability of UAS for Aviation and Aerospace Education and Training

As discussed, ERAU-W integrates drones as educational tools across various courses and programs, providing students with hands-on experience in uncrewed aircraft systems. Particularly, in the undergraduate program Bachelor of Science in Uncrewed & Autonomous Systems (BSUS) students engage in designing, building, and flying a variety of uncrewed aircraft, gaining practical experience with industry-grade equipment and facilities. According to the program learning outcomes, these course projects equip students with skills necessary for understanding drones and robotics. Graduate of the program achieve high success in career and

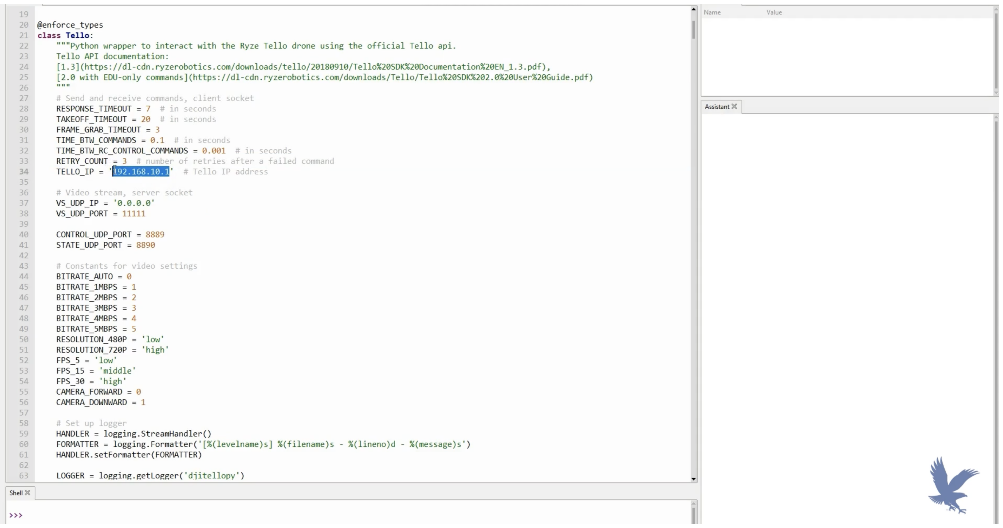

Figure 3: Python IDE for Programming Drone

employment in the Uncrewed Systems Economy [3].

The very high overlap between electric propulsion concepts, mechatronic aspects and computer science between drones and innovative electric aircraft creates high synergy and applicability in both areas respectively. There is no clear distinction between UAS and drones and electric aircraft concepts, other than the fact that the first category is uncrewed. This can be by design and purpose, but also due to optionally piloted systems or platforms where a human is a mere passenger, rather than a pilot.

A B

Figure 4: Comparison of a typical electric motor for a drone (A) and a standard layout electric motor (B)

The Bachelor of Science in Uncrewed & Autonomous Systems uses Computer Aided Design (CAD) in courses, such as UNSY 318 - Uncrewed Aircraft Systems Robotics to introduce components of aerial robotic platforms and the associated electric propulsion. Figure 4 shows the difference between typical electric drone motor and a standard electric motor used in industry purposes in CAD models.

The design principles used for larger and more complex drones merge the foundational concepts of traditional aeronautical engineering with cutting-edge, digitally driven robotics innovations. In

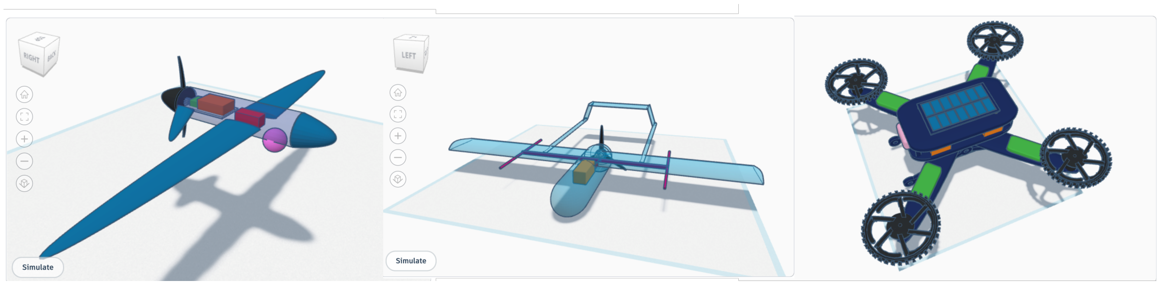

Figure 5: UAS/drone design studies by students of UNSY 318 in TinkerCAD

UNSY 318, students gain hands-on experience by creating and designing aerial platforms tailored for diverse applications using the software TinkerCAD. Figure 5 demonstrates exemplary results and concepts of application-driven drone platforms designed in CAD for UNSY 318. The use of CAD software enhances the achievement of course learning outcomes by facilitating conceptual design, topology development, and component selection for specific applications.

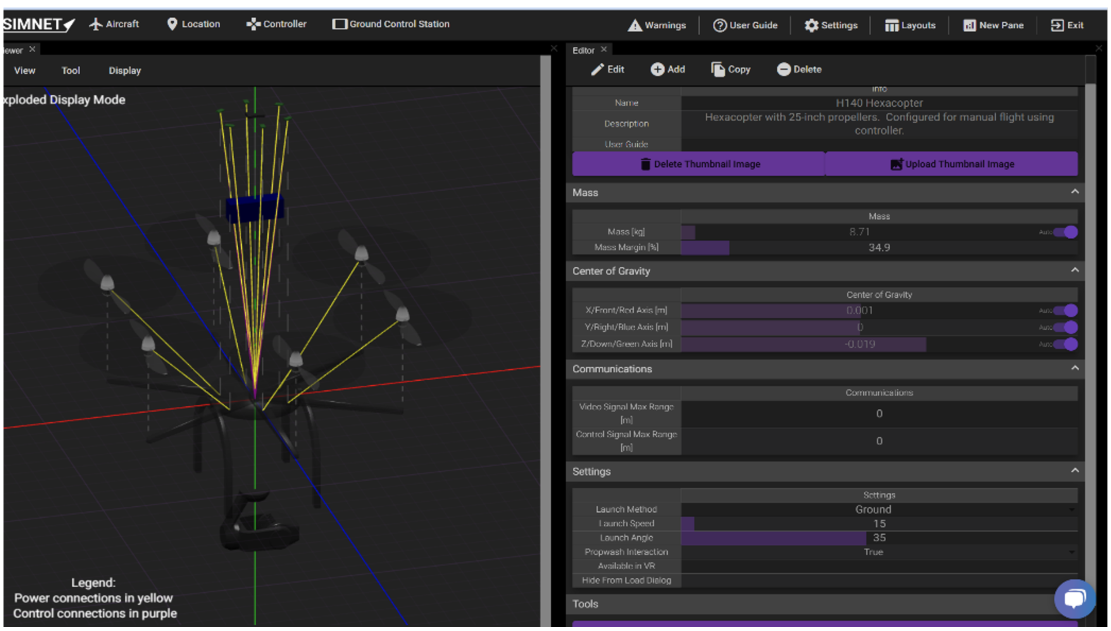

Figure 6: Screen capture of H140 Hexacopter model in SIMNET with power connections displayed

SIMNET is a powerful simulation tool that exemplifies the integration of lessons learned across the courses of the BSUAS program and related curricula. This versatile software is designed for the design and optimization of drone platforms, with a particular emphasis on electric motor integration. It offers detailed modeling capabilities, enabling the simulation of motor performance, energy consumption, and thermal behavior under diverse operating conditions.

With its ability to experiment with various motor configurations and control algorithms, SIMNET empowers designers to select the most effective components to achieve optimal power-to-weight ratios and energy efficiencies. Furthermore, its integration of aerodynamic and structural analyses promotes a comprehensive approach to drone platform development. By bridging theory and application, SIMNET supports innovation in electric propulsion systems, aligning perfectly with the goals of advancing knowledge and practical skills in drone and aerospace technology.

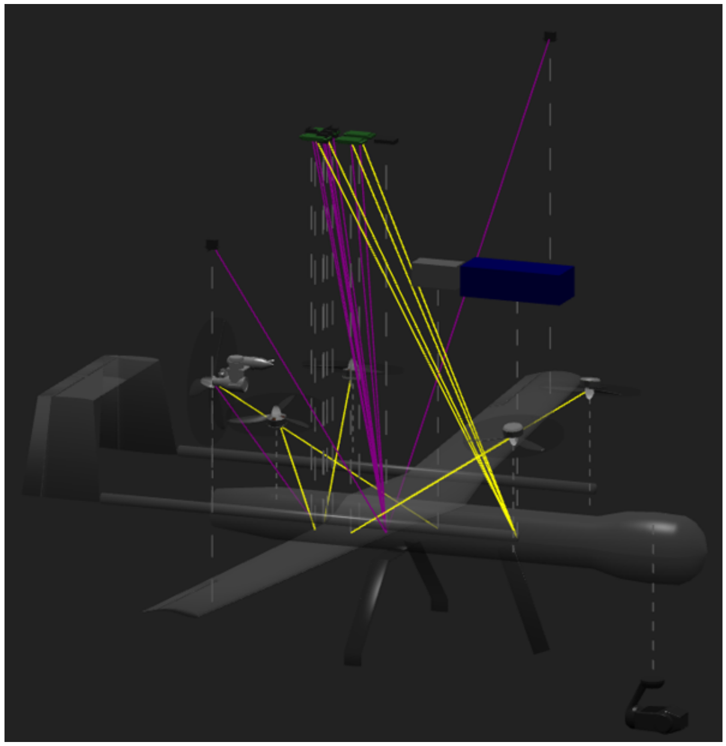

Figure 7: Q400 VTOL in SIMNET

Since its implementation in 2022, the utilization of SIMNET in UNSY 315 has successfully integrated the learning outcomes related to robotic drone components with the essential skills and knowledge required for advancing future aviation and aerospace propulsion and platform concepts. Figure 6 and 7 show exemplary how the simulation software SIMNET is relating to aerospace engineering and design principles by using drones as template for electric propulsion platforms.

Conclusion

In this work-in-progress paper, we offer a case study of teaching the concept of electric propulsion in aviation with drones or CAD software for online undergraduate students. As electric propulsion—widely recognized in the drone sector—gains prominence in aviation, aerospace, and even automotive industries, lessons learned can be leveraged to enhance outcomes in higher education. We believe drones serve as practical, accessible, and cost-effective tools for teaching electric propulsion concepts in an online environment or in a brick-and-mortar classroom setting. Their versatility enables students to gain hands-on experience, bridging theoretical knowledge with real-world applications. Additionally, the modular course structure in online programs offers the flexibility to seamlessly integrate electric propulsion topics into the curriculum while maintaining coherence and adherence to ABET-required learning outcomes.

Small drones have long been used in training and education as foundational tools for transitioning to larger drones and eVTOL systems. Their interdisciplinary nature makes them ideal for shaping future learning concepts in electric propulsion, a field poised for significant growth in the aviation and aerospace sectors. To align with this evolving vision, course content, teaching materials, and faculty qualifications will need to adapt and advance accordingly.

References

[1] Olasile Babatunde Adedoyin and Emrah Soykan. "Covid-19 pandemic and online learning: the challenges and opportunities". In: *Interactive learning environments* 31.2 (2023), pp. 863–875.

[2] John Butler. "Drones in education: Bridging theory and practice at Embry-Riddle". In: *Journal of Aviation Studies* 14 (3 2021), pp. 45–59.

[3] Embry-Riddle Aeronautical University. *Uncrewed and Autonomous Systems Career Opportunities — worldwide.erau.edu*. `https://worldwide.erau.edu/colleges/aviation/department-aeronautics-graduate-studies/uncrewed-systems-career-opportunities`. [Accessed 10-01-2025].

[4] European Union Aviation Safety Agency. *Electric aviation: Preparing the workforce for a sustainable future*. `https://www.easa.europa.eu`. [Accessed 10-01-2025]. 2023.

[5] FAA. *Workforce readiness for the unmanned aircraft sector*. `faa.gov`. [Accessed 10-01-2025]. 2023.

[6] Majid T Fard et al. "Aircraft distributed electric propulsion technologies—a review". In: *IEEE Transactions on Transportation Electrification* 8.4 (2022), pp. 4067–4090.

[7] *Flying hydrogen 'air taxi' makes record 523-mile trip with fuel to spare — thesun.co.uk*. `https://www.thesun.co.uk/tech/29540952/joby-aviation-flying-air-taxi-new-york/`. [Accessed 10-01-2025]. 2023.

[8] Scott A. Ginder, Janice E. Kelly-Reid, and Farrah B. Mann. *Enrollment and Employees in Postsecondary Institutions, Fall 2017; and Financial Statistics and Academic Libraries, Fiscal Year 2017*. Tech. rep. U.S. DEPARTMENT OF EDUCATION, 2019.

[9] Chris Janke et al. "Using Small UAS for STEM Education: Introducing Robotics and Mechatronics with Drones". In: *35th Florida Conference on Recent Advances in Robotics*. May 2022.

[10] Hyeonmin Jeon et al. "A study on the development of job training curriculum for operation of electric propulsion ships". In: *Journal of International Maritime Safety, Environmental Affairs, and Shipping* 6.1 (2022), pp. 91–98.

[11] Athula Kulatunga and Ajith Wijenake. "Power Electronic Skills for Electric Powertrain in Marine Propulsion". In: *2023 CIEC*. 2023.

[12] Robert Lea. *Vertical Aerospace shrugs off Rolls-Royce exit from flying taxis — thetimes.co.uk*. `https://www.thetimes.co.uk/article/vertical-aerospace-shrugs-off-rolls-royce-exit-from-flying-taxis-q3cns86m3`. [Accessed 10-01-2025]. 2023.

[13] Pitambar Paudel. “Online education: Benefits, challenges and strategies during and after COVID-19 in higher education.” In: *International Journal on Studies in Education (IJonSE)* 3.2 (2021).

[14] Smruti Sahoo, Xin Zhao, and Konstantinos Kyprianidis. “A review of concepts, benefits, and challenges for future electrical propulsion-based aircraft”. In: *Aerospace* 7.4 (2020), p. 44.

[15] R. Smith and T. Jones. “Integrating autonomous systems into aviation education”. In: *Aerospace Education Review* 10 (2 2022), pp. 22–35.

[16] *The future of air mobility: Electric aircraft and flying taxis*. `https://www.mckinsey.com/~/media/mckinsey/featuredinsights/thenextnormal/the-next-normal-the-future-of-air-mobility.pdf`. [Accessed 10-01-2025]. 2021.

[17] The International Civil Aviation Organization (ICAO). *Guidelines on electric aircraft safety and operations*. [Accessed 10-01-2025]. 2023.

[18] Emily Tobler. *Clearing the Air: Opportunities & Hurdles in Electric Aviation — 4AIR — 4air.aero*. `https://www.4air.aero/whitepapers/clearing-the-air-opportunities-amp-hurdles-in-electric-aviation`. [Accessed 10-01-2025].

[19] Patrick Wheeler et al. “Electric/hybrid-electric aircraft propulsion systems”. In: *Proceedings of the IEEE* 109.6 (2021), pp. 1115–1127.

[20] Tracy L Yother and Mary E Johnson. “Identification of Student Outcomes for the Electric Propulsion Aircraft Industry Based on Industry-Developed Consensus Standards”. In: *2023 ASEE Annual Conference & Exposition*. 2023.