Developing diverse workforce for Oklahoma Aerospace Industry - Collaboration Between a Two year and a Four year Institutions

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Work in Progress: Developing diverse workforce for Oklahoma Aerospace Industry - Collaboration Between a Two year and a Four year Institutions

Unmanned Aerial Systems (UAS) have become popular in the past two decades because of their key role in numerous military applications, which range from aerial support of troops involved on the battlefield to surveillance and border patrol. The versatility of UAS platforms make it extremely appealing for several civilian applications, and considerable cost reduction for critical components has made this technology a powerful resource for private operators.

In this paper we present a collaborative effort with the objective of establishing a competitive UAS educational program at the Rose State College (RSC, a two-year institute) and creating a pipeline to develop a UAS workforce in Oklahoma. The approach modified freshman and sophomore aerospace and mechanical engineering courses at RSC to incorporate UAS design into applicable courses. Experiential learning opportunities involving UAS are included through class projects. Modifying the "Introduction to Aerospace Engineering" course at the University of Oklahoma (OU, 4-year institute) and applying the theoretical concepts learned in class to real examples involving UAS. UAS platforms are not considered as mere special cases, but will be given proper attention both in class and through dedicated homework assignments and projects.

We also investigate pipeline of students from RSC to OU. Many of the RSC students attending selected undergraduate classes at OU decide to continue their education by pursuing a bachelor's degree in engineering. This positive trend is encouraged by providing UAS students at RSC to perform undergraduate (UG) research at OU. This paper presents different activities to establish curriculum and collaboration between the two institutions to support Oklahoma's workforce.

UAS Workforce – Motivation

Unmanned Aerial Systems (UAS) are quickly breaking down barriers when it comes to technological advancement. UAS have become popular in the past two decades because of their key role in numerous military applications, which range from aerial support of troops involved on the battlefield to surveillance and border patrol. The versatility of UAS platforms make it extremely appealing for several civilian applications, and considerable cost reduction for critical components has made this technology a powerful resource for private operators. For instance, Google [1], DHL [2], and Amazon [3] are investing considerable effort in designing drones for rapid distribution of parcels from their warehouses to buyer's doorstep. Moreover, Facebook [4] is designing solar-powered UAS to relay ultra-high speed wireless signals and allow fast internet access to secluded areas. In addition, UAS are being used to monitor the availability of water resources, control the density and quality of crops on extended areas, and observe livestock over vast areas. UAS are now also employed in professional filmmaking and to gather footage in sporting events. UAS are also becoming a key asset to support disaster relief [5], search and rescue missions, and law enforcement [6] operations, since they can carry a large variety of thermal and optical sensors. With these rapid adaptations of UAS across industries the technician education needs to be formalized.

With the growing potential for UAS usage worldwide, preparing the next generation of UAS operators and technicians is more important than ever. Rose State College (RSC) and the

University of Oklahoma (OU) have been given the opportunity to work together to transform students into leaders in the growing UAS industry in Oklahoma. Together, RSC and OU are excited to provide students with a strong competitive advantage and formal training, giving them experiential-based knowledge on the basics of UAS technology and how these machines operate. In this paper. preliminary efforts to establish UAS workforce pipeline is presented.

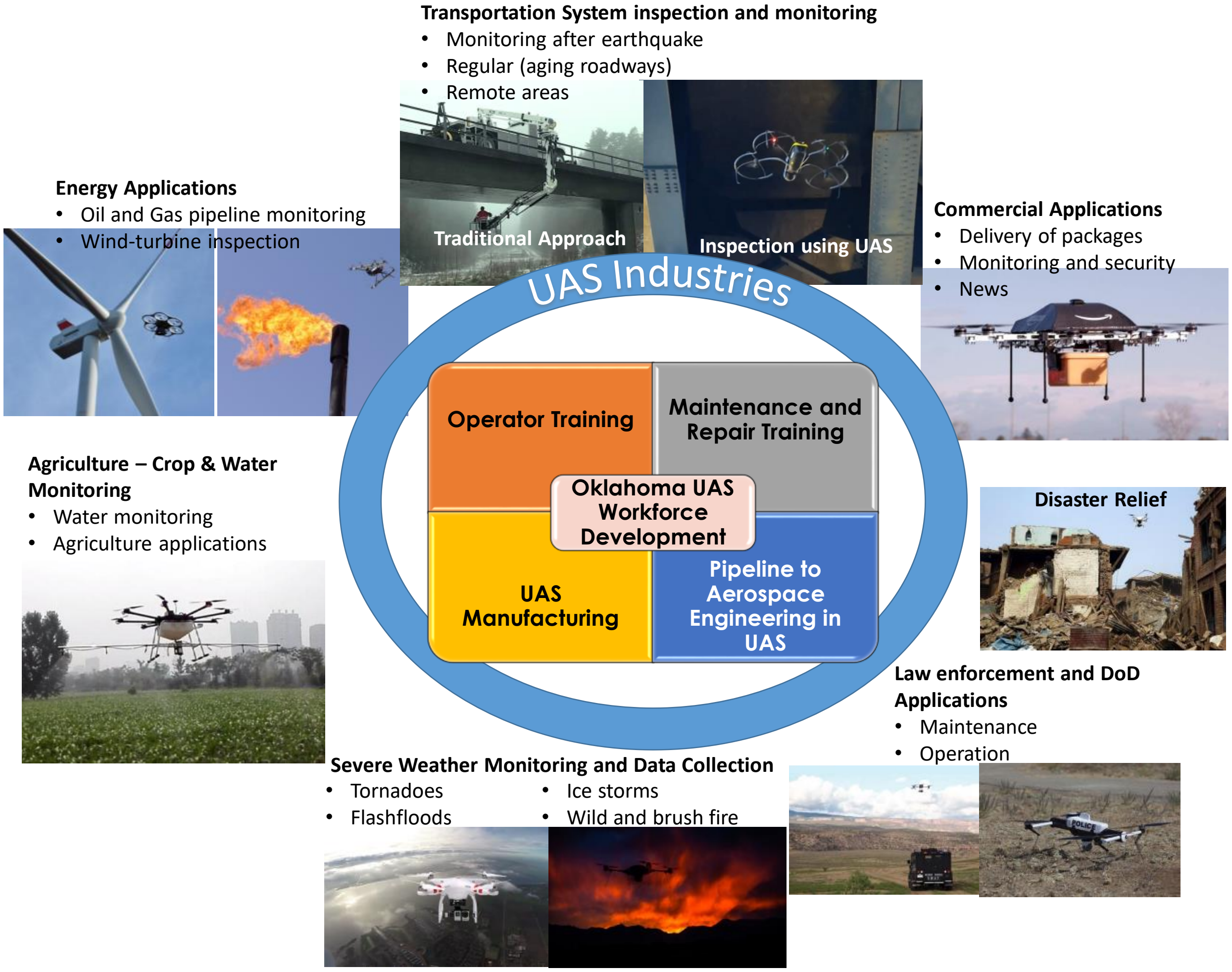

Figure 1: Oklahoma UAS workforce development for a range of applications

Oklahoma and Regional Need

The Oklahoma Department of Commerce has identified 1) energy, 2) information and finance, 3) transportation and distribution, 4) agriculture and biosciences, and 5) aerospace and defense [7] as the top five economic sectors that are strongest with regards to wealth generation, growth potential, and wages. Approximately one quarter of Oklahomans are employed directly or indirectly in the energy industry and about 20% of all jobs in the State are tied to the oil and natural gas sectors. Oklahoma hosts several strategic oil and gas pipelines, such as the Seaway Crude Pipeline System. Oklahoma has an abundance of available wind energy, and in recent decades has drastically increased the number of electricity-generating wind turbines in the rural, western portion of the state. Agriculture is an important industry in Oklahoma, according to the Oklahoma Department of Agriculture, Food and Forestry, in 2015 Oklahoma was characterized by 1,231 square miles of water areas and ranked eighth in the Nation for acreage dedicated to farming [8]. The State has careers in research and development, commodity production and distribution, and fertilizer manufacturing. Aerospace and defense are also big contributors to jobs in the state provides over 143,000 direct and indirect jobs; Tinker Air Force Base, the world largest aircraft-maintenance complex, is based in Oklahoma City.

The ability of UAS to reach remote locations and cover long distances can provide immeasurable support to the agricultural and energy industries in Oklahoma. However, applications that can benefit from the use of UAS are not fully appreciated and exploited. For instance, Lidar can be installed on UAS to measure the depth of the numerous lakes in Oklahoma and the height of crops. Alternatively, UAS can be used to capture images of crop fields for analysis by agronomists to assess the amount of fertilizers and pesticides to spread. In addition, UAS can be equipped with heat sensors to detect and monitor livestock. Multi-spectral antennas can be mounted on aerial platforms to measure the crop density and forecast the quality and quantity of harvest. UAS can carry high-definition cameras to visually inspect extended segments of pipelines or wind turbines (Figure 1). These few examples highlight the role of UAS to support two pillars of Oklahoma industry. It is estimated that globally there are only 80,000 operators currently involved in UAS design, production, operation, and management. This relatively small number will grow in the next few years and increase the need for a well-trained workforce to meet the challenges. A robust evidence based training programs in UAS will ensure that Oklahoma pillar industries have access to qualified personnel and cutting-edge technology.

The Need for Dedicated UAS Training Programs

Training specialized workforce to meet the industry needs, presents unique challenges, which cannot be addressed by merely considering UAS as smaller aircraft. One of the points of strength of UAS are that they are unmanned, and hence are not as strictly regulated as conventional aircraft. The absence of tight regulations allows the UAS market to evolve very rapidly, according to the industry demands, and UAS designers, maintainers, and operators must be able to rely on a solid engineering and technical background to anticipate and satisfy the rapidly changing needs of the numerous activities involving drones. In August 2016, the Federal Aviation Administration (FAA) issued the Small Unmanned Aircraft Rule (Part 107), concerning the use of UAS for research, educational, and commercial purposes. These regulations will evolve over the years and it is therefore important to train future operators fully aware of the current restrictions on the use of UAS and are capable of complying with future ones.

Smaller UAS, such as quadrotors and hexrotors, are now available in most toy and electronics stores. Connecting these devices to a mobile phone or a portable computer is seamless and any user is ready to fly a UAS a few minutes after it has been removed from its box. However, there are several safety, security, and privacy issues, which preserves some of the risks associated to conventional aircraft. One of the goals of this project is to reach out to local middle- and high-schools with intents of piquing students' interest in pursuing a career in STEM, showing how their math and physics concepts are applied to aeronautics, and presenting safe avenues to play with "drones."

Technology is continuing to change perspectives and ways of doing things; making people more efficient. UAS could have a similarly large impact in the future, even less than the next 20 years. As UAS technology becomes more and more commercialized, there will be high demand for workers who understand and know how to operate them. There is a need to prepare the next generation of students for the new technology, with Oklahoma being at forefront when this technology becomes mainstream in five to 10 years.

Bridging the Gap Between Midwest City and Norman

Representatives from RSC and OU saw an opportunity for Oklahoma to be positioned as a leader in UAS technology and wanted to find a way to provide students with the proper education to understand and operate drones. Considering the large oil, gas, and engineering industries within the state, both institutions recognized the potential for a partnership to develop a curriculum surrounding drones. Key players from both schools met and discussed how they could work together to develop and educate students on UAS.

<u>Developing Drone-Centered Curriculum</u>

Globalization [9] has put engineering education [10, 11] and the profession at a challenging crossroad. The competitiveness of the U.S., which is linked to standard of living, is dependent on our ability to produce a large number of sufficiently innovative engineers and skilled technical professionals [12-15] to develop solutions to complex open problems [16], and adapt easily to the changes as a result of rapid developments in a field [17]. Serious concerns have been raised about whether the U.S. is adequately preparing the next generation workforce [18] for the demands of an increasingly high-tech, interdisciplinary workplace [9, 19]. We envision a UAS workforce, technicians and engineers, engaged at a higher-level cognitive skills (Analyzing, Evaluating, and Creating in Bloom's Taxonomy [20, 21]) working together, to design, develop, operate and advance UAS industry. An UAS education program for technicians and engineers needs to provide necessary technical background in multiple aspects:

- *Fundamentals of programming*: this skill is a pillar for designing autonomous UAS and many other STEM applications such as the more general, platform of robotics.
- *Aerodynamics*: the first step toward flight is knowing how the aerodynamic forces are generated. This will help considerably in the design of effective controls.
- *Flight dynamics and control*: flying is the art of governing aerodynamic forces and this ability has to be enhanced when operating small and underactuated devices, such as UAS.
- *Payloads and applications*: It is important for UAS technicians to understand range of sensors that can be installed on UAS and the constraints they imply on the vehicle.
- *Materials* and *manufacturing*: small and medium UAS are built using plastic materials, composites, or solid foams, which guarantee satisfactory strength and very low weight. These materials need to be carefully understood to exploit their properties to the maximum extent. Using nonmetallic materials to manufacture UAS requires modern techniques, such as 3D printing to create UAS components or molds to shape these components.
- *Regulations*: educated workforce must be aware of the regulations regarding their field. UAS are currently raising several concerns ranging from privacy to insurance liability and interference with conventional aircraft. Future UAS operators must be aware of all these critical issues to be competitive on the job market and successful in their work.

In addition to technical skills, next-generation technical professionals and engineers need to be adaptive enough to address changing needs, and address unforeseen challenges [22-24]. Education systems and frameworks for engineering education need to support development of technical aptitude and general (meta) competencies [25, 26], that is, those skill sets that enable students to communicate effectively, work in teams, operate in complex organizations, meet quality standards, and transfer task-specific skills to new challenges or tasks [27, 28]. Our proposed development of advanced UAS technical professionals will be grounded in Kolb's [29] work, which provides a model of experiential learning with four stages (i) *Concrete Experience*: the learner must be willing and actively involved in the experience; (ii) *Reflective Observation*: the learner must be able to reflect on the experience; (iii) *Abstract Conceptualization*: the learner must possess and use analytical skills to conceptualize the experience; and (iv) *Active Experimentation*: the learner must possess decision making and problem solving skills, in order to use the new ideas gained from the experience.

From an epistemological perspective, experiential learning aligns with constructivism, which posits that learners construct meaning from their experiences [30]. Our UAS education program has been designed with use of *experiential learning* to merge theoretical concepts and applied experiences. Having an interactive component is imperative for students to properly learn UAS technology. The goal isn't necessarily to only teach students about how to use drones, but for it to complement the already existing coursework for engineering students.

Achieving Goals, Objectives, and Outcomes

Our objective of establishing a competitive UAS educational program at RSC and creating a pipeline to develop a UAS workforce will be pursued by attaining the four goals discussed in this section.

<u>Goal 1: Supporting increased competencies of future UAS technicians</u>

Departments of aerospace engineering and aviation provide educational services aimed at training aerospace engineers, pilots, and technicians who are able to design, build, operate, and maintain conventional aircraft. Although the fundamental concepts of aeronautical engineering apply to any aerial vehicle, UAS are quite peculiar for their shape, material, endurance, controllability, energy sources, regulations, business functions, and operational environment. Therefore, the collaborators will pursue the following objectives:

Objective 1: Restructuring the current technology program at RSC to train technicians specialized in assembling, operating, and maintaining UAS.

Approach: Each core course will be grounded on the *Experiential Learning* approach, where students learn by designing, building and operating, evaluating what experience is successful or unsuccessful, reflecting on how to improve unsatisfactory attempts, and conceptualizing their experiences.

One of the major components for this project was the need to add a full time faculty member in the Engineering and Science division at OU. A significant portion of the funding requested in this project was allocated for the salary of this faculty member. Dr. Jiyoon Lee has served a second year in this position, and continues to be funded by this project.

Additionally, funds were budgeted to purchase a large 3-D printer capable of using modern, high strength thermoplastics to be utilized in UAS design and prototypes. A decision was made to purchase two smaller 3-D printers instead of one large one. A Stratasys F-170 and a Markforged Mark II were both purchased during this evaluation period with the funds which were originally allocated for the purchase of a larger Stratasys F-370. The two smaller printers combined have proven to augment RSC UAS design capabilities more than the larger printer alone, and the decision resulted in a cost savings.

OU have continued work to integrate UAS into Technology courses. OU have purchased some commercially available UAS' that can be used to introduce the electronics involved with UAV into the course titled "Introduction to Electronics". Additionally, UAS topics can be introduced in a Technology course titled "Technology Practices" to provide students with an understanding of UAS' current and future impacts on Technology. Finally, the variability between individual, commercially produced UAS will be used for a hands-on, real world example in a course titled "Statistical Quality Control"

Objective 2: Modifying freshman and sophomore aerospace and mechanical engineering courses at OU to incorporate UAS design into applicable courses.

Approach: Experiential learning opportunities involving UAS will be included through class projects. Modifying the "Introduction to Aerospace Engineering" course at School of Aerospace and Mechanical Engineering (AME) and applying the theoretical concepts learned in class to real examples involving UAS. UAS platforms will not be considered as mere special cases, but will be given proper attention both in class and through dedicated homework assignments and projects. This was achieved through:

- A design project into the course titled "Materials, Design, and Manufacturing Processes" where students reviewed available literature, selected a material appropriate for the body of a drone, and designed a drone for manufacturing via 3-D printers.
- Case studies in a course titled "Strengths of Materials" where students analyzed the material properties and capabilities of materials used in the design of UAS.
- Working with committees within the Engineering and Science Division at RSC to identify opportunities to incorporate UAS based activities, examples, or theories into the Math and Physics courses taken by Engineering and Technology students. A project module for a course titled "Graphics and Design" was implemented, where students designed and 3-D printed attachments for UAS to be used in future Physics classes and labs. Math and Physics faculty to develop UAS modules for integration into Physics and Calculus courses. RSC Physics department plans to begin having students conduct lab experiments using UAS purchased as part of this program in place of more traditional Physics laboratory activities as early as Summer 2019. RSC Math department offered a Special Topics course in the Spring 2019 semester titled "Mathematics of Drones" where students and the instructor investigated opportunities to develop single variable and multiple variable Calculus applications regarding UAV's.
- An extracurricular "Drone Team" comprised of approximately 10 OU students was formed. Their current goal is to get hands on experience with designing, building, and flying drones without the limitations and restrictions of an academic environment. The group will actively seek out competitions in which they may be able to compete.

- OU in conjunction with the Federal Aviation Administration (FAA) hosted a Safety Seminar titled: Sharing The Skies Safely - Aircraft and Drone Operations in Central Oklahoma. The Seminar was held on April 13, 2018, and included discussions about safe and legal operation of drones and UAV. Airspace restrictions around airports and Air Force bases were also discussed. FAA's website indicates the event was attended by 44 registered guests.
- The content of UAS-related modules for Introduction to Aerospace has been refined to 1) maximize the overlap between the course "Introduction to Aerospace Engineering" taught at OU and the one being designed at OU; 2) better prepare students for future classes, where UAS-related modules have been introduced.

<u>Goal 2: Pipeline to 4-year degree in Aerospace Engineering</u>

Many of RSC students attending selected undergraduate classes at OU decide to continue their education by pursuing a bachelor's degree in engineering. We intend to promote this positive trend by pursuing the following objective:

Objective 3: As trained UAS specialists, OU students will attend "Introduction to Aerospace Engineering," a sophomore-year class at OU. Most competitive UAS students at OU will perform undergraduate (UG) research at OU.

OU has a 16,000 cubic feet indoor facility for UAS education and research. The facility is equipped with state-of-the-art computers and high fidelity cameras to provide exact position and velocity of moving objects to test control algorithms for aerospace applications. OU is located approximately 20 miles away from the main campus of OU, and students can easily commute between both institutions. Moreover, the credit transfer process for OU students, who decide to pursue a bachelor's at OU, will be simplified.

In addition to courses and UG research at OU, the collaborators intend to stimulate constructive interactions between OU and OU students through several joint activities:

Objective 4: Organizing joint events, where OU and OU students display their achievements and discuss their objectives in the field of UAS technology. These events will be crucial to introduce local industries to OU students and display their achievements.

The close collaboration established over the years between our institutions guarantees the successful implementation of this objective. Moreover, AME at OU contributes every year to the AIAA (American Institute of Aeronautics and Astronautics) conference, which involves 12 universities in the region. Faculty members at OU will be involved in the organization of this event, which provides an ideal setting for OU students to interact with colleagues from local institutions.

- Graduate students from OU delivered a seminar on UAVs at OU. The primary goal of this seminar were to attract students to the newly established UAV program at OU, while presenting fundamental results on UAV autopilot design. A good portion of students in the audience had already been exposed to UAV design projects through the newly established UAV program at OU and received the content of this lecture quite well.

Goal 3: Increase UAS and STEM awareness to middle and high school students

The ready availability of UAS and their ease of use are nourishing the enthusiasm of younger generations for flight. The collaborators want to leverage this popular moment for UAS and encourage middle and high school students to pursue a career as aerospace engineers or specialized technicians, and educate next generation to a safe and responsible use of UAS:

Objective 5: Organizing open house day at OU in collaboration with OU to illustrate the latest advances in the areas of UAS and, more in general, aerospace engineering to Oklahoma middle and high school students. This event will comprise a visit to OU for a live demonstration of autonomous UAS operations.

Involvement and active participation of STEM teachers is fundamental to effectively attracting young people to pursue a career in aeronautics and, more generally, STEM subjects. Specifically, we plan to establish a productive dialogue with local STEM teachers and discuss integration of basic aerospace engineering concepts in science and math classes. Hence, we propose the following objective:

Objective 6: Organize a yearly one-day event at OU in collaboration with OU to meet STEM teachers and introduce fundamentals of aeronautics and aerospace engineering in Oklahoman middle and high schools through curricular and extra-curricular activities.

UAS can be fun to fly, but also a potential source of harm if not properly used. Moreover, the Federal Aviation Administration has recently issued the “Small unmanned aircraft rule” (Part 107), which regulates the use of UAS. It is important that the general population are educated about correct and safe use of UAS..

In response to the “increase UAV and STEM awareness in middle and high school students” (Objectives 5 and 6) RSC collaborators have:

- participated in STEM Leadership Day at Gordon Cooper Technology Center and visited with over 300 high school students about UAV’s, 3-D printing, Engineering, and Technology
- organized and conducted a “Drones Drones Drones” course during RSC’s 2018 Kids College, a summer program for children of all ages
- developing multiple courses for RSC’s 2019 Kids College covering UAV’s and 3-D printing for different age groups of children

Discussion and Questions

The team is involved in the developing a program collaboratively to address need of trained UAS workforce and a pipeline for 4-year degrees in aerospace or other engineering. Some of the observations are:

- The team has noticed that the UAS technology can excite middle and high school student towards UAS. The team is not in the process of trying to determine how many of these participants pursued education in STEM, especially at the two-year college.
- Integration of UAS in physics and mathematics has allowed to attract students to UAS and engineering early in their college career.
- Design, manufacturing, and flying of UAS, using additive manufacturing, has combined two attractive technologies. This has also allowed better understanding of different concepts.

It is not clear at this point of time how many of the students at RSC will be pursuing BS degrees in engineering, with interest in UAS. Some of the questions that remains to be answered are:

- How do we integrate technology training to support UAS workforce in a more robust model?
- How do we integrate critical thinking that will allow for growth and new innovation for future UAS growth?

This is a work-in-progress and we expect have more in-depth discussions and results on these issues in the future.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant Nos. 1700647 and 1700640.

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