

## **Board 16: REU Site in UAV Technologies: Assessment of the Program after the Second Year**

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Erika DeJonghe, Ph.D. received her doctorate in clinical psychology from Michigan State University in 2007. She is an associate professor in the Department of Psychology & Sociology at California State Polytechnic University, Pomona. She currently serves as the Interim Associate Dean for the College of Letters, Arts & Social Sciences. Dr. DeJonghe has two primary areas of scholarly focus, violence against women and the experiences of women who are under-represented in their academic disciplines. Dr. DeJonghe is also a licensed clinical psychologist. Her areas of clinical interest include family therapy, play therapy, and child group therapy, with a particular focus on work with children and families recovering from trauma.

# **REU Site in UAV Technologies: Assessment of the Program after the Second Year**

## **Abstract**

*The Research Experience for Undergraduates in UAV Technologies* project is funded by the NSF's EEC Program. The main goal of this project is to increase undergraduate students' participation and interest in research on unmanned aerial vehicles (UAV) technologies. Undergraduate students from 2- and 4-year institutions are involved in multidisciplinary research projects at Cal Poly Pomona. The REU site supports 10 students for 8-10 weeks of summer research per year, with the projects focusing on research on the Dynamics and Control of UAVs, Collision Detection & Avoidance System for UAVs, Machine Learning, Artificial Intelligence, Computer Vision, and Flight Test experiences. Another goal is to attract students from community colleges to STEM programs at 4-year institutions and encourage the participants to pursue their studies for graduate degrees.

This paper discusses the assessment of the Program after the second year of the Program. The REU site has been successful in meeting its goals and objectives. Most of the participants are now pursuing their educational or professional career in the area of UAVs and other related areas. The Program has also been successful in motivating the participants to graduate degrees in STEM fields. Some of the participants are already pursuing their studies for a Master's degree or are planning to apply to Master's/PhD programs. Most of the community college students have transferred to 4-year institutions for degrees in engineering. Also, all the participants have presented their work at student and/or professional conferences. This has helped the participants improve their written and oral communication skills. Assessment results after the second year of the Program are presented.

## **I. Introduction**

The goal of this REU Site is to provide research experience to undergraduates and expose them to state-of-the-art UAV technologies in a multidisciplinary environment. The research focus of the Site is UAV dynamics & control, increased autonomy of UAVs, and their applications.

Recently, UAVs have seen increased usages for many applications that include traffic and infrastructure monitoring, surveillance of disaster-hit areas, search and rescue, environmental gas monitoring, package delivery, aerial photography, border patrol, precision agriculture, etc. The UAV industry is one of the fastest growing sectors of aerospace industries. However, lack of desired level of autonomy has prevented mass adoption of these vehicles for many applications. Also, there is a lack of professionals entering the workforce for UAV related jobs and lack of interest among undergraduates to pursue their studies for advanced degrees in this area. The REU Site's objectives are to prepare a strong workforce for the needs of industry and academia in this area.

This paper presents the assessment of the Program outcomes and effectiveness of the Program in meeting the Program goals and objectives. The Program successfully hosted the second cohort of REU participants in the summer of 2018.

The following paragraphs discuss the sample projects that the participants were involved in, professional development opportunities for the participants, and assessment results.

## II. Sample Projects

The projects are being designed to increase students' interest in UAV technologies, engineering, and computer science to develop their research skills. The goal of the Program is to involve the REU participants in the UAV related cutting-edge research projects. The UAV Lab in the Aerospace Engineering Department at Cal Poly Pomona provides a suitable research environment for the participants.<sup>1</sup> The following paragraphs describe the projects that the 2018 summer REU participant were involved in. The projects designed for the 2017 REU Participants were presented in Ref. 1. The Program continued to provide the participants with an opportunity to gain knowledge on the application of engineering and computer science to UAV technologies, acquire skills necessary to conduct meaningful research, understand research process, and learn laboratory techniques.

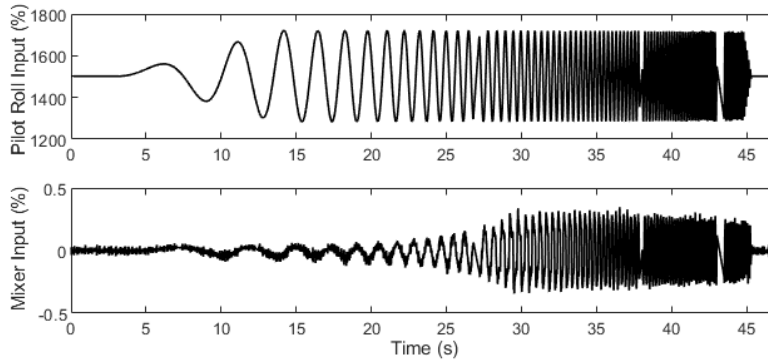
### A. Development of Flight Dynamics Model of a Multicopter

This project involved an REU participant in flight-testing, data collection, data processing, and system identification of a multicopter UAV, which is shown in Figure 1. The participant worked with a more experienced student on this project, which also involved a student from a community college.



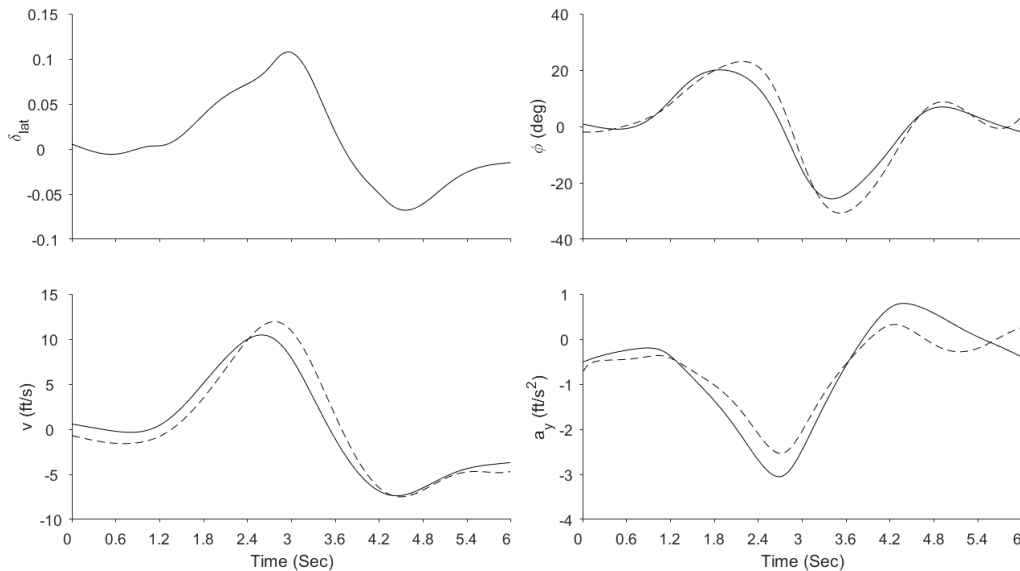
**Figure 1. Y6 multicopter UAV from 3DR.**

The multicopter was flown extensively for the data required for the identification and verification of flight dynamics models.<sup>2</sup> Figure 2 shows an example of the collected flight data. The collected data was first processed using MATLAB<sup>®</sup> software, and then converted into a frequency response using CIPHER (Comprehensive Identification from FrEQUENCY Response) software.<sup>3</sup> The frequency response was then used for the identification of transfer function and state-space dynamics models of the Y6 multicopter in hovering flight.<sup>2,4</sup> Different tools within the CIPHER software were used to analyze the data and for the model identification.<sup>3</sup>



**Figure 2. Roll frequency sweep data.**

Figure 3 shows an example of the identified model response compared with the flight data for lateral dynamics of the vehicle. The pilot input to the vehicle was roll input ( $\delta_{lat}$ ). As can be seen, the model response tracks the flight data accurately for lateral velocity ( $v$ ), roll angle ( $\phi$ ), and lateral acceleration ( $a_y$ ).



**Figure 3. Comparison of model response (dashed) with flight data (solid) for lateral dynamics.**

The student has continued working on the project even after the culmination of the summer REU program, and is a co-author of the paper that has been accepted for presentation at and publication in the proceedings of a professional conference.<sup>2</sup>

## **B. Autonomous Navigation of UAVs in the GPS-Denied Indoor Environments**

This project involved some REU participants along with a student from a local high school. The students worked on autonomous navigation of lightweight and small multicopters in GPS-denied indoor environments and target recognition for search and rescue missions. The use of lightweight multicopters makes them ideal for maneuvering through tight spaces and locating targets in shorter time. Simultaneous Localization and Mapping (SLAM) techniques and Collision Avoidance

Systems (CAS) were used to develop capabilities to navigate the vehicle in the GPS-denied environments.<sup>5,6</sup> Using a LIDAR and camera, it is possible to create a map of indoor environments as well as determine and keep track of the UAVs in the constructed map. The targets can be identified using onboard image processing. An RPLidar was used in conjunction with HectorSLAM algorithm for localization and mapping.<sup>7</sup> A Mobius Actioncam was used for the target identification. The identification software runs on an NVIDIA Jetson TX1 microcomputer, which communicates with the onboard Pixhawk flight controller, while also transmitting data to a ground station using XBee radio modules. Neural networks are used for the target identification. Figure 4 shows an overall architecture of the project.



**Figure 4. Overall architecture of the project for autonomous navigation of UAVs in indoor environments for search and rescue missions.**

### III. Professional Development of Participants

As reported previously,<sup>1</sup> we continued with the professional development of the participants. Several workshops were conducted during the course of the program that included Ethics in Engineering and Science, Graduate School Application Process and Financial Support, Resume Building, Improving Oral and Written Presentation Skills, and Industry Careers. These workshops had direct impact on the success of the students as discussed below. In addition, the participants had an opportunity to tour the facilities of Northrop Grumman Corporation (NGC) and NASA Armstrong Flight Research Center (AFRC). Both NGC and NASA AFRC are involved in UAV research and/or development. The participants were also made aware of the Federal Aviation Administration (FAA) regulations pertaining to the use of UAVs.

### IV. Assessment of the Program

The outcomes of the Program were assessed through the extent to which the following Program objectives were achieved: 1) Actively involve a diverse group of undergraduate students (including Hispanic/Latino students and women) from 2- and 4-year institutions; 2) Increased

interest among the participants in UAV Technologies; 3) Knowledge of flight dynamics and control of UAVs; 4) Recognition of the need for, and an ability to engage in life-long learning; 5) Improvement of written and oral communication skills; 6) Opportunity to learn other disciplines; and 7) Interest among students to pursue graduate degrees.

The evaluation of the Program was done by an external evaluator not involved with the REU Program. The evaluator conducted pre- and post-participation surveys from the Participants as well as collected the faculty mentor evaluations of the participants.

### **A. Participant Demographics**

The first REU Program was offered in summer of 2017. The 10-week Program started on June 19, 2017 and ended on August 24, 2017. 10 participants were selected from an applicant pool of 93. The second REU Program was offered from June 18, 2018 and ended on August 10, 2018. For the second year, the program had to be shortened to 8 weeks since the university converted to semester system from quarter system with a fewer summer weeks available for the summer of 2018. 11 participants were selected from an applicant pool of 126. Out of 126 applications, 86 applications were complete. Remaining applicants were not considered as their application packages were not complete.

Both the cohorts included a diverse group of students. Out of 21 participants so far, 5 participants were female, nine were Hispanics, and one was Native American. Each cohort included two students from community colleges. Thus, the Program has been successful in meeting the objective of involving a diverse group of students including underrepresented minorities.

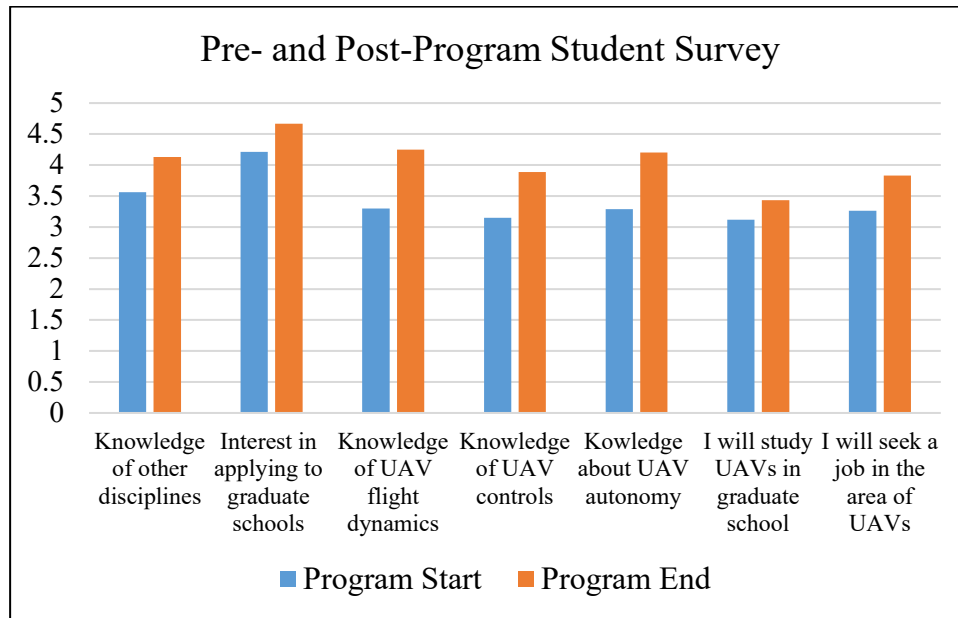
### **B. Evaluation of Impact on Student Success**

For both the years, pre-program surveys assessed the students' interest in the UAV technologies, knowledge of the UAV technologies (a content knowledge measure), and the students' attitudes toward and commitment to ongoing learning. During the last week of the summer Program, the evaluator had a second meeting with the participants. The post-test reassessed areas covered in the initial evaluation as well as included free-response items for the students to provide qualitative feedback on their experiences in the REU Program. Assessment of student learning after the first year of the program was presented in Ref. 1.

In general, the participants expressed overall satisfaction with the program and gratitude for their experiences. Some of the comments include: 1) "It was one of the best experiences and has expanded my knowledge and skills," 2) "I believe for many of us, this program was much more influential than we thought it would be," 3) "Through the tours, I became more interested in pursuing a research-oriented job," 4) "They [my plans] did change. I want to go to grad school in a field related to UAVs," 5) "I massively improved my coding knowledge, as well as learned the ability to solve problems without relying on any advisor help," 6) "Working with others taught me how to work with and bring out people's strengths to apply," 7) "This program allowed me to learn a lot more about the complexity of real-world problems currently being worked on using UAVs. It also allowed me to see the real applications of the theory being taught to us," and 8) "The best was flight testing. The tours were nice as it showed real world application."

These comments from the participants indicate that the Program was able to instill self-directed learning in the participants.

Figure 5 shows the student responses to pre- and post-participation survey questionnaire. It is seen that the average participant responses improved significantly post-participation compared to the pre-participation responses.



**Figure 5. Student responses to pre- and post-participation survey questions.**

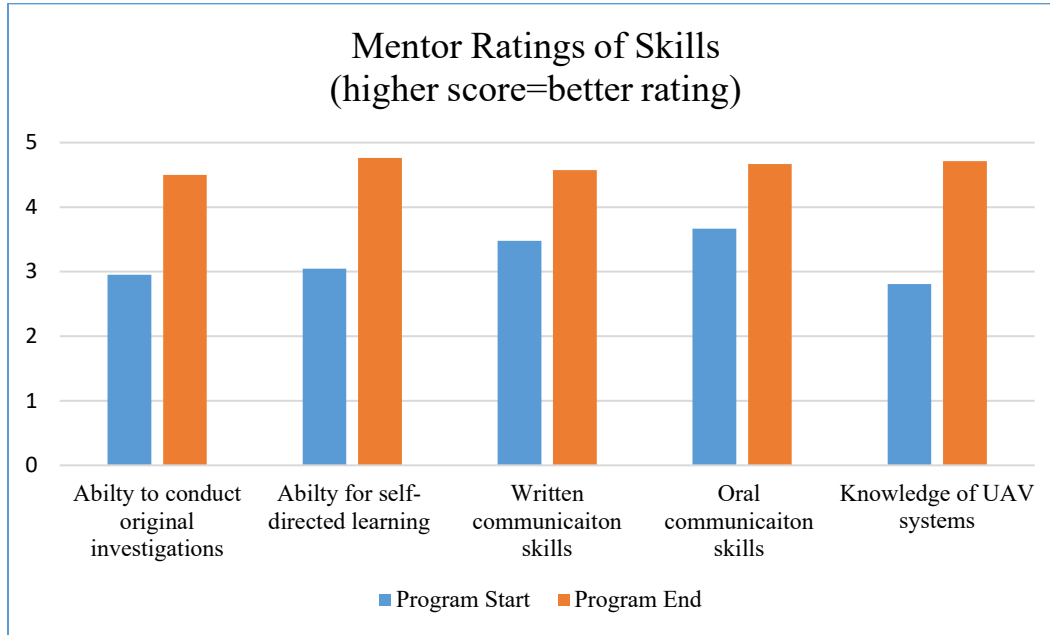
A total of 11 participants from 2017 and 2018 Program continued their involvement in the UAV research projects. The REU site has been able to motivate the students for career in UAV Technologies, which is one of the main objectives of the Site.

Three REU participants and one non-participant but supported by the REU funding have so far graduated with BS degrees in Engineering and Computer Science. All four students graduated with GPAs of more than 3.0. One graduated Magna Cum Laude and two graduated Cum Laude. Also, 3 of the 4 participants from Community Colleges have transferred to 4-year institutions for BS degree in Engineering. The fourth students has been applying to 4-year institutions for a STEM degree.

Of the three participants who have graduated with a BS degree so far, one student is continuing his studies on to Master's in Computer Science. One graduating senior has been accepted for Master's in Mechanical Engineering, and will be working as a Graduate Research Assistant on autonomous UAVs and aerial robotics. His eventual goal is to get a PhD degree in engineering.

The evaluator also met with the faculty mentors during the last week of the Program. The faculty mentors provided feedback regarding the students' capacity for self-directed learning and original investigation as well as the participants' skills for communicating scientific and engineering

concepts. Figure 6 shows the mentor evaluations of the participants at the start and end of the Program.



**Figure 6. Mentor evaluation of the REU participants (average of 2017 and 2018 ratings).**

Comparing the mean ratings of the student skills at the start and end of the program (collected retrospectively at the end of the program), mentor evaluations indicated statistically significant changes in the average skills ratings for the participants in the course of the Program.

All the participants presented their work at the student conferences. Also, 9 participants so far are main authors or co-authors of papers presented at and published in the proceedings of professional conferences including AIAA SciTech Forum and International Conference on Unmanned Aerial System (ICUAS).<sup>8-11</sup> Out of these, four participants were the presenters at these conferences. Two participants presented their work at the REU Symposium organized by Council on Undergraduate Research. This shows improved written and oral communication skills of the participants. One more participant's work has been accepted for presentation at a professional conference.<sup>2</sup> Some other participants are continuing their work and have already obtained publishable results.

This shows that the REU Program has so far been successful in meeting its goals and objectives. The Program has had significant impact on student success and has been successful in motivating them for career in UAV technologies and graduate degrees.

### **C. Participants' Recommendation for Improvements**

While the participants' comments were generally very positive, the participants had some recommendations for improvements that include: 1) "Make it known that students are not allowed to take summer courses in the application," 2) "Clearer direction as to what resources we have



access to,” and 3) “Having professors/advisors work hands on with them the first few weeks to get the group started.” We will take the participant comments as well as the recommendation of the evaluator into account for improving the quality of the Program.

## V. Conclusion

Both faculty mentors and participants reported marked gains in skills and knowledge of the participants of both the 2017 and 2018 summer Programs. This is a particular area of strength. The participants continued to highlight the interpersonal experience of working with fellow students as a major strength of the program. The participants also benefited from the tours of the research labs and field trips, which seemed to have an influence on their career choice.

There were significant improvements in skills for communicating scientific and engineering concepts via written and oral methods. Participants also showed increased interest in pursuing graduate degrees.

The Program participants were diverse with regard to race, ethnicity, and gender. About fifty percent of the participants were underrepresented minorities. The program also included women, although they comprised only 24% of the cohorts. We will consider targeted efforts to recruit more women into the program. Results of these efforts and other success stories will be reported in future.

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