Department of Computer Science & Engineering
The University of Texas at Arlington

Project Charter
CSE 4316: Senior Design I
Fall 2022

Top Drone: Mavericks
Raytheon Drone Project

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Revision History

Revision	Date	Author(s)	Description
0.1	09.12.2022	RC, JB, JL, JM, PI	document creation
0.2	10.03.2022	RC, JB, JL, JM, PI	complete draft

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1 Problem Statement

This project is being undertaken in response to the growing demand for Unmanned Aircraft Systems (UAS). With drone technology, there is increasing flexibility in the tasks that can be accomplished. A recent example of drones being used in places such as Ukraine has demonstrated their effectiveness on battlefields in dispatching enemies while protecting friendly troops. In the near future, global militaries will prefer to have autonomous machines fight for them over putting their troops at risk. This student team aims to conduct research in the area of autonomous drones that can destroy enemy targets on the ground in order to meet this growing demand for UAS. Student team members will gain a wide variety of drone technology knowledge along the way. Other areas outside of war zones can benefit from these aspects, such as disaster relief, land surveying, and police work.

2 Methodology

By researching and developing software that allows for the full autonomy of airborne drones, the student CSE team will address the rapidly growing demand for autonomous aircraft systems. Under the mentorship of Raytheon, the team will develop an autonomous ground vehicle and drone through coordination with undergraduate students studying Electrical Engineering (EE) and Mechanical and Aerospace Engineering (MAE). By utilizing ArUco markers, the drone's camera will enable it to identify ground targets during flight to distinguish friends from enemies. Upon detecting hostile ground vehicles within a 50-yard-by-50-yard area, the drone will fire a laser at the moving ground vehicle to indicate if the drone has successfully engaged and hit the target.

3 Value Proposition

The project is sponsored by Raytheon Technologies, an American multinational aerospace and defense company. In its role as a world leader in aerospace and defense, Raytheon understands the importance of investigating and developing unmanned systems. Raytheon will get to work with and monitor student teams and guide them as they develop unmanned air and ground vehicles through a two-semester-long project. Raytheon can use this mechanism to identify top graduates, promote corporate recruitment, and explore the latest technology trends. In addition to providing students with hands-on experience in unmanned systems, this project will also benefit the University of Texas at Arlington. Additionally, the university gains valuable experience in constructing unmanned systems through the involvement of professors in the student teams. It is critical to the university's success and distinction to involve students in research and industry standards like this.

4 Development Milestones

- Requirements Review - September 2022
- Project Planning - September 2022
- Project Charter first draft - October 2022
- System Requirements Specification - September 2022
- Architectural Design Specification - September 2022
- Project Proposal & Presentation - October 2022
- Mid-Year Report - December 2022
- Prototype Creation - December 2022
- Prototype Demonstration - December 2022
- Targeting Showcase 1 - January 2023
- Targeting Showcase 2 - February 2023
- Targeting Showcase 3 - March 2023
- Targeting Showcase 4 - April 2023

- CoE Innovation Day poster Presentation - April 2023
- Final Project Presentation - May 2023

5 Background

As of 2025, unmanned aircraft systems are expected to create more than 100,000 jobs, according to a study by the Association for Unmanned Vehicle Systems International (AUVSI) [1]. Having said that, it is clear from recent war zones like Ukraine that drones have been used effectively. However, it is usually necessary for humans to control drones. As warfare becomes more dangerous and technologies advance, militaries are looking for ways to minimize their casualties. Rather than putting their troops in harm's way, military leaders want autonomous vehicles that can take down hostile targets. It is Raytheon's goal to support student research and innovation in autonomous vehicle design by sponsoring them in this showcase competition. As a result, Raytheon can scout and recruit top graduates from universities participating in the showcase. To simulate real-world target recognition for unmanned systems, students will identify ArUco markers placed on moving ground vehicles. Furthermore, students will gain industry insight while collaborating across multiple teams and coordinating for an eight month project that requires extensive documentation and coordination.

In addition to providing Raytheon with technology for national defense purposes, the AUVSI report estimates that the integration of these systems with the National Airspace System (NAS) between 2015 and 2025 will generate more than 80 billion dollars [1]. This is due to the many applications for UAS in the following areas: wildfire mapping, agriculture, disaster management, law enforcement, cinema, environmental monitoring, and freight transport [1]. There are no prior relationships between Raytheon and the student CSE team. Nevertheless, Raytheon may find students they wish to hire after graduation through its sponsorship of this project.

6 Related Work

In order to complete this project, a drone that is autonomous will need to be built. A camera on the drone must identify ArUco markers, and a laser must target Ace Combat sensors placed on top of targeted ground vehicles. Moreover, the drone must be equipped with a GPS & RTK system. UTA's CSE department has a long history of working on drone projects and has curated a list of parts that have proven competitive in competitions of this type.

A similar project was completed by the UTA CSE team for the 2021-2022 year for Raytheon, which included autonomous flight, GPS, and RTK systems. As a result of these similarities, their project will prove useful for building the 2023 drone and figuring out what parts would work best. Since their drone did not have the capability of targeting moving vehicles and sensors with lasers, it can serve as a basis for the 2023 drone, but additional sources to do the other tasks will need to be found [2].

The first major milestone to completing this project is to build the drone. It is also necessary to learn how to connect the drone to Mission Planner to map out its flight patterns. The following is an example of how a drone is constructed and how it is connected to Mission Planner [3]. They have a Raspberry Pi onboard their drone, but the goal is to eliminate the use of a single-board computer attached to the drone and instead connect to it wirelessly, which will reduce the drone's weight and eliminate the constraints that come with single-board computers. Another difference this year is the use of ArUco markers on top of moving ground vehicles to identify moving targets. It is possible to accomplish this task using a popular library called OpenCV, which has detailed documentation [4]. Another source explains how to use OpenCV to detect ArUco markers and how to land on them in video [5]. An additional source of information on the implementation aspect of OpenCV to identify ArUco markers is helpful for this project.

The University of Texas at Dallas (UTD) won the 2022 Raytheon drone competition. A description and diagram of the winning drone can be found on UTD's website. This drone contained two LiDAR sensors [6]. Due to the radar spinning extremely fast to scan the surrounding area, LiDAR creates a lot of inertia. The drone being built by the UTA CSE team for the 2023 competition will avoid using rotational LiDAR. A LiDAR sensor will be used to measure the drone's height and speed. To eliminate the complications that can arise with omnidirectional LiDAR scanners, a unidirectional and non-rotational LiDAR sensor will be used. By minimizing inertial forces caused by omnidirectional LiDAR scanners, the team can control the drone more easily because it does not exert a lot of inertial forces.

7 System Overview

It is assumed that the drone will be equipped with a single-board computer in the diagram below. Using a single-board computer, the drone would be able to process the tasks it is required to carry out for each showcase by executing them through the single-board computer. It is still unknown whether the computation part of the project will be allowed to be performed wirelessly (i.e. without the need for an onboard computer to control the drone) by the team. Once a decision has been made, a new version of this document will be prepared.

It is expected that a flight controller will be mounted on the drone in order to control the motors' speeds, therefore allowing horizontal and vertical movement in the drone to take place. It will be necessary to run Mission Planner on a computer (either onboard or via a wireless connection) in order for it to function. With the help of Mission Planner, drone movements can be mapped for the drone so it can be controlled as needed. With Mission Planner, autonomous vehicles can communicate with a ground station via an interface which can be accessed from most Windows operating systems. As a result of using Mission Planner, the team will have the option of creating their own autonomous flight paths. Further, the computer will run a program that has the capability of identifying ArUco markers as well as functioning as a link between the computer and the flight controller.

For aiming at the ace combat sensors that are located on all hostile ground vehicles, there needs to be a laser attached close to the camera to increase accuracy. There are two choices available to the camera once it detects an ArUco marker. The camera can either turn and aim at the enemy vehicle or move to a position where the drone could use its laser to shoot moving ground vehicles.

There will be a dedicated flight controller that will be connected to GPS and RTK systems. It is expected that the drone motors will be connected to electronic speed controllers, which will in turn be connected to the dedicated flight controller.

To power all of the components of the drone while it is in flight, the drone will need to be equipped with a battery. There is no doubt that batteries can add a lot of weight to a drone, so this is also something that should be considered when deciding which batteries to use. Battery size and location should also be considered in order to ensure that the camera or laser is not interfered with or blocked by the battery in any way.

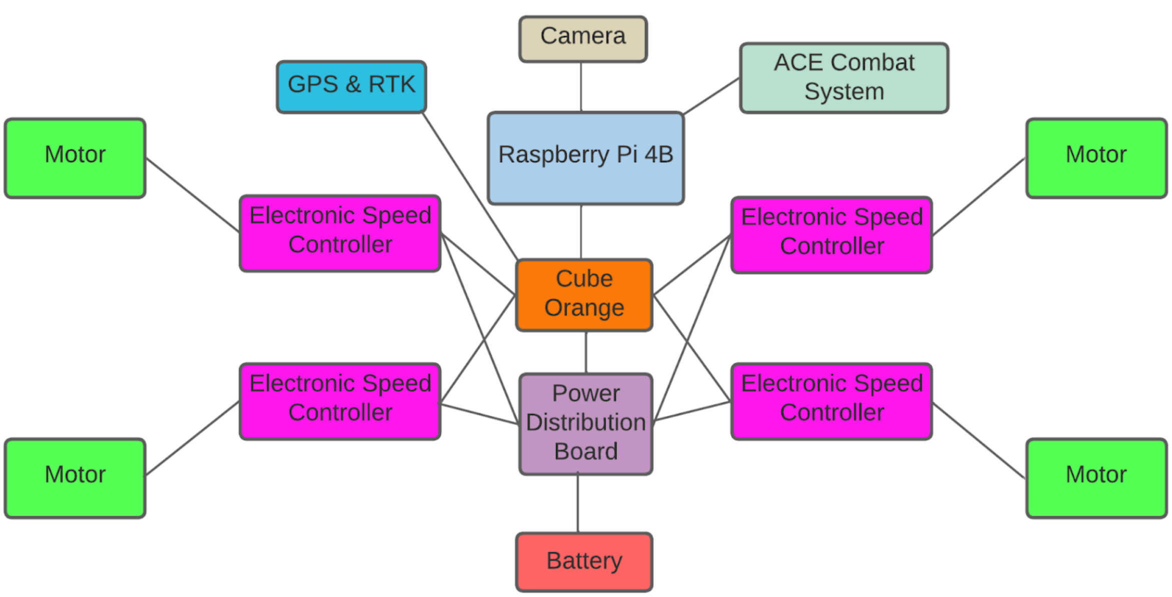

Figure 1: Diagram of the System Overview

8 Roles & Responsibilities

Raytheon's stakeholders include the following two members:

- Gretchen Mock (RIS Senior Leadership) - Raytheon Mentor & Point of Contact
- Jesse Lee (Competition Council) - UT Student Mentor

For this project, the CSE team consists of the following five students:

- Javier - Student Team Lead & Point of Contact
- Jaedyn Brown - Student Team Member & SCRUM Master
- Robert Carr - Student Team Member & FAA Certified UAV Pilot
- Ja'Lun Morris - Student Team Member
- Pearl Iyayi - Student Team Member

Currently, it is unclear what specific roles each member will be assigned, such as computer vision or autonomous flight. The current team lead and point of contact is Javier Lopez, who manages the student team and represents the team to McMurrough, the Raytheon mentors, and the student leader of the entire project. As well as being a student team member, Robert Carr will get his FAA UAV pilot certification. Prior to demonstrations, Robert will need to pass the relevant examinations and ensure that the drone is safe to fly within regulations. Jaedyn Brown holds the position of SCRUM master and is therefore primarily in charge of laying out the sprint backlog for each sprint, and giving time estimates for how long each of those tasks should take. The position of SCRUM master will be maintained throughout the duration of the project as Jaedyn's role.

9 Cost Proposal

As the CSE team for the Autonomous Drone Project, most of our tasks delegated are in relation to the drone's build, and building software to get it to perform its necessary tasks. Taking into account money from sponsorship, our approximate budget is $1600. The drone build cost estimate is based on insight from our professor who is gathering the parts. The drone must be acquired in order to participate in the competition. A student must become FAA certified as a requirement for the competition. The drone build cost will be covered through a variety of department funds. The FAA certification will be covered by the budget afforded by Raytheon. Major expenses of the drone build include ordering a single board computer, ordering a microcontroller, and a GPS module to be fitted to the drone.

9.1 Preliminary Budget

In addition to the parts below, FAA Pilot Certifications will be required. Two certifications ($175 each) will be acquired for a total of $350.

Part Type	Price	Quantity	Total Cost
Companion Computer	$185	1	$185
Microcontroller	$485.99	1	$485.99
Brushless Motor Set (4PCS)	$40-$50	1	$40-$50
Electronic Speed Control Set (4PCS)	$40-$50	1	$40-$50
GPS and RTK	$325	1	$325
Camera	$25	1	$25
Propeller Set	$15-$20	1	$15-$20
Battery	TBD	1	TBD
Radio Receiver	$20-$30	1	$20-$30
Telemetry	$96	1	$96
LIDAR Distance Sensor	$30	1	$30
Radio Transmitter	$130-$160	1	$130-$160
Brushless Camera Gimbal	$50-$60	1	$50-$60
Optical Flow Sensor	$20-$30	1	$20-$30
ACE Combat System	$39.95	1	$39.95

Table 1: An overview of the project's components and their prices

9.2 Current & Pending Support

- $5,000 will be provided by Raytheon Technologies
- $800 will be provided by the University of Texas at Arlington
- The CSE department may provide additional funding.

10 Facilities & Equipment

In order to complete this project, the following facilities and equipment will be required:

- UTA Maverick Stadium
- Senior Design Lab located in ERB 335
- 3D printer
- Makerspace
- Campus grounds

University of Texas at Arlington's Makerspace can be used if team members need to print any 3D parts. The Makerspace provides a 3D printer for parts printing. The Makerspace offers soldering stations that will be required for the drone build. These machines are already present in the lab and will not need to leave the room. Located in room 335 of the Engineering Research Building, the senior design lab will be accessible 24/7. Obtaining access to the lab requires a student ID and a pin number. UTA Maverick Stadium will host the showcase demonstrations when the competition is held. Flight testing may be conducted within the designated lab, or performed elsewhere on campus grounds where permitted.

11 Assumptions

- Drone flight tests can be conducted on campus.
- Dedicated campus lab spaces will be made available for the software development team to meet and develop software.
- The ground vehicle will be constructed by the EE and MAE teams.
- Hardware development of the unmanned ground vehicle is primarily the responsibility of the EE and MAE teams.
- It is expected that the EE and MAE teams will have a working ground vehicle available to the software development team when it is needed.
- The EE and MAE teams will have a drone of their own.

12 Constraints

- The project must be completed by April
- For each challenge demonstration, the project must be in a working state
- Raytheon provides $5,000 for team-wide development costs. In the event that we go over this, we will need to look for outside funding
- FAA UAV Requirements for Educational Users and Institutions of Higher Education must be followed
- The project demo deadline must be met with a demonstrable portion of the project
- Raytheon must receive the project source code after the competition is completed
- A "kill switch" must be implemented on drones that overrides the mission and lands them safely and/or enables manual overrides
- A UAV that is being flown must have propeller guards
- Before the Innovation Showcase, a pre-flight inspection will be conducted to ensure UAS are safe to fly and comply with all rules and regulations
- It is FAA-required that UAV be registered
- FAA drone pilot certification must be obtained by at least one student
- Whenever IR lasers are fired by the drone, a buzzer should sound, the timestamp should be saved into the software logs, and the drone's LEDs should light up

13 Risks

Risk description	Probability	Loss (days)	Exposure (days)
Software team experiencing delays caused by other teams	0.5	30	15
Drone crash during testing	0.8	14	11.2
Part availability may delay shipping	0.6	14	8.4
Replacement of faulty or damaged drone hardware	0.4	12	4.8
Outsiders messing with and breaking the drone	0.05	14	0.7

Table 2: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

14.1.1 Project Charter

The initial version of the Project Charter will be uploaded on October 3nd 2022. The final version of the Project charter will be uploaded on April 30th 2023. There is a possibility that the charter will be updated sprint to sprint as more information is received. Sections such as 14.2, 14.2.1, 14.2.5, etc, are most likely to be updated.

14.1.2 Systems Requirements Specification

The initial version of the SRS document will describe the features and behaviors of the Drone and the software we expect to utilize within the project. The initial version of the SRS document will be submitted on October 24, 2022. The final version of the SRS document will be submitted on April 30th, 2023 when the final version of the project charter will be submitted. Should changes occur after the initial version of the SRS document is submitted, we will update the appropriate document/s to reflect those changes.

14.1.3 Architectural Design Specification

November 14th, 2022 will be the deadline for the initial Architectural Design Specification (ADS). The final deadline for the ADS will be April 30th, 2022. Each team member can edit the ADS at any time, and all changes will be reflected for everyone on a shared Google Doc. In the process of developing the project, we will continue to update this shared document as needed.

14.1.4 Detailed Design Specification

The initial version of the Detailed Design Specification (DDS) will reflect the state of hardware and software components at that time. If any changes are made to the hardware or software being utilized in the project after the initial version is submitted, then our team will update the DDS to reflect those changes. The initial version of the Detailed Design Specification will be submitted February 26th, 2023. The final version of the Detailed Design Specification will be submitted April 30th, 2023.

14.2 Recurring Sprint Items

14.2.1 Product Backlog

As soon as the SRS is created, a backlog item will be created for each requirement. These items will be prioritized by necessity to get a test drone built, while also having working software. The handling of our team's backlog will be done by the Scrum Master. The team's backlog will be issued through a shared Google Sheet.

14.2.2 Sprint Planning

There will be eight sprints throughout the duration of this project. Each of them would be planned taking into account lessons learned from previous sprints. The following methods will also be implemented:

- Planning a sprint meeting after examining the team's availability
- Go over backlog and assigning ownership of tasks to team members
- Confirm new issues, impacts, and dependencies

- Reach a group consensus on time estimations

14.2.3 Sprint Goal

The sprint goal will be determined by the team during a meeting before the start of the sprint. The best way to keep the project stakeholders involved is by giving a report on our sprint goal to our sponsor on the first Friday of every sprint.

14.2.4 Sprint Backlog

The SCRUM master will be primarily in charge of managing which items are placed in the sprint backlog, and how much time is estimated for each of those tasks. An excel spreadsheet will be used to maintain our sprint backlog, update time estimates, and display a burndown chart.

14.2.5 Task Breakdown

Individual tasks will be first assigned by members who volunteer for that task. Time spent on tasks will be logged by each individual within the team on our Excel spreadsheet.

14.2.6 Sprint Burn Down Charts

When each team member logs their hours worked for each task in the Excel spreadsheet, there will be a Burn Down chart that gets updated automatically. The sprint spreadsheet will include specific sprint backlogs in which the general tasks for that sprint are divided into smaller parts. This will indicate which team member(s) worked on each subtask. The subtasks are not recorded per hour, yet. The total number of hours expended by each team member is included in a table for every sprint backlog.

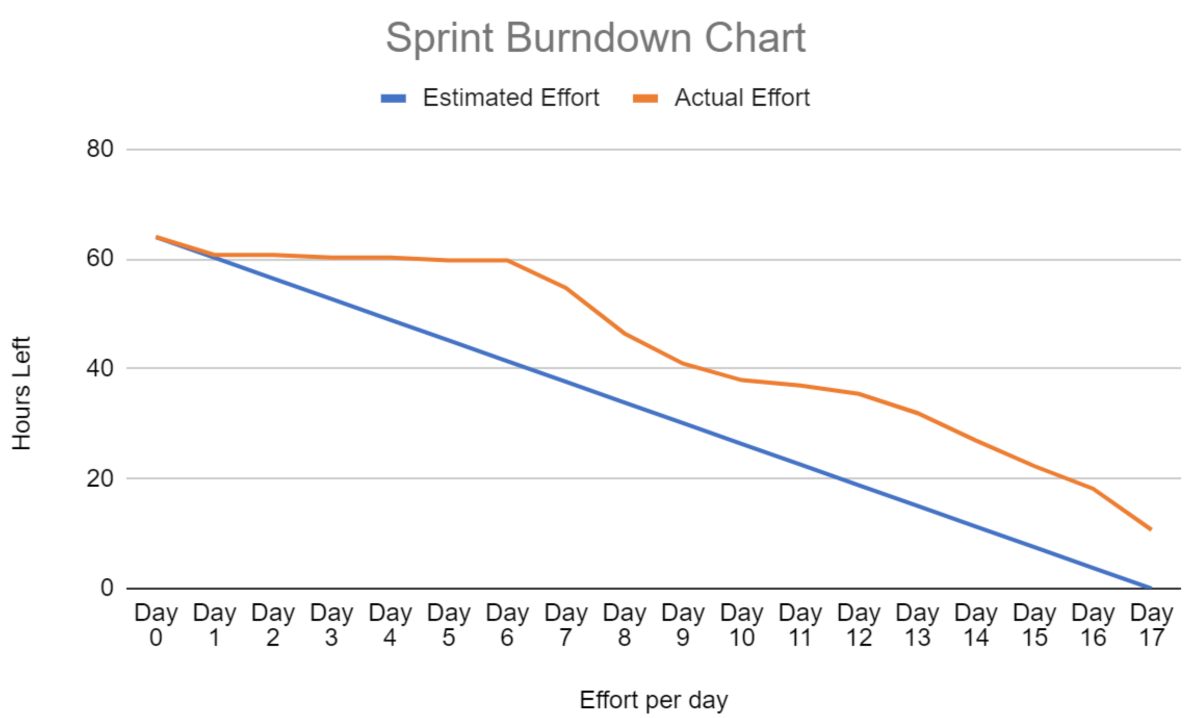

Figure 2: Example sprint burn down chart

14.2.7 Sprint Retrospective

Following each sprint, the team will hold a retrospective meeting to discuss what went well and what could be improved. We will assign team tasks to each team member based on the sprint goals. Assigning tasks will keep team members accountable. Each task will be due at the end of each sprint.

14.2.8 Individual Status Reports

Every week, there will be a Discord meeting to give a status report. Detailed information regarding a team member's goals, issues, and progress will be included in the team member's status reports.

14.2.9 Engineering Notebooks

Software development team members are expected to update their engineering notebooks at the end of each sprint in order to hold each other accountable for their work. It is essential that each team member is able to communicate effectively regarding their engineering notebooks in order to hold one another accountable. A mid-sprint meeting can be used to discuss the targeted number of pages for the current sprint. To ensure quality control, the SCRUM master must sign off as a witness for each engineering notebook page.

14.3 Closeout Materials

14.3.1 System Prototype

In the final system prototype the drone will contain features that have been discussed in previous sections. To reiterate, the final system prototype will include the following: GPS and RTK, camera for IR blasting and QR code detection, a cube orange flight controller, and software that configures autonomous flight. There will be a Prototype Acceptance Test with the customer, they expect to see a prototype by the end of the fall 2022 semester. There will be off-site testing in the Maverick stadium as it is intended to be an outdoor competition if there are favorable weather conditions.

14.3.2 Project Poster

In addition to an architectural diagram, the poster will also explain Python use cases and describe the components of the drone.

14.3.3 Demo Video

As certain parts of the project become demonstrable, demo videos will be provided. Demo videos will demonstrate key aspects of the project and how they behave and respond in real-world environments. Videos will vary in length depending on what is being demonstrated.

14.3.4 Source Code

Version control and source code maintenance will be handled by the team using Git and GitHub. The source code will not be accessible to the public at any time during the project's lifecycle. It will however, be available to Raytheon and the entire student team. A zipped folder from the GitHub repository could be provided at any time to enable users to view the source code at any time. License information, if included, will appear at the top level of the folder structure to make it easy to locate.

14.3.5 Source Code Documentation

Our team does not currently have any plans for what tool may be utilized in order to assist in documentation. These tools will be explored in deeper detail and when a decision is made, the Project Charter will have documentation produced in LaTeX.

14.3.6 Hardware Schematics

The hardware schematics will be updated when the parts that will be used to assemble the drone for the CSE test run are confirmed. Right now its is known that there will be soldering needed to make some electrical connections.

14.3.7 User Manual

This project's user manual will be available at a later date. A setup video may be included in the user manual explaining how the hardware is configured and how to run the code. In the case a video is included, the visual instructions will show how to run the project in a simple and straightforward manner.

References

[1] "The Economic Impact of Unmanned Aircraft Systems Integration in the United States," Association for Unmanned Vecicle Systems International, Tech. Rep., 2013.

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[5] "PRECISION LANDING | with OPENCV and ARUCO Markers," OPENCV and ARUCO Markers, Tech. Rep.

[6] "UT Dallas CS/ECE Team Place First in the 2022 Raytheon Unmanned Aircraft Systems (UAS) University Innovation Showcase," UT Dallas, Tech. Rep., 2022.