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

SRS Document
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	10.6.2022	RC, JB, JL, JM, PI	document creation
0.2	10.26.2022	RC, JB, JL, JM, PI	complete draft

Contents

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1 Product Concept

This section describes the purpose, use and intended user audience for the production of all related content pertaining to the production of the Raytheon sponsored Drone Project. This project's intended use case is to compete in the UAS University Innovation Showcase in the Spring of 2023.

1.1 Purpose and Use

The team's focus for this project is to construct a drone that will compete in the UAS University Innovation Showcase in the Spring of 2023. The drone must fly autonomously, clearing a specified space occupying 50 yards x 50 yards. The drone must identify hostile ground vehicles, and aim a laser towards a sensor housed on each ground vehicle to imitate a hit. This project is being completed solely for the competition, and all work related to this project will cease upon submission of all finalized versions of project documentation.

1.2 Intended Audience

This project is sponsored by Raytheon. If this project were to be used for purposes beyond the Innovation Showcase, then it is likely this work would be used for commercial use owned by Raytheon. Given their own customers, the product would likely be utilized for government purposes.

2 Product Description

As part of the 2023 Raytheon UAS Innovation Showcase, the University of Texas at Arlington CSE team is developing an autonomous drone. This section describes the product's primary operational aspects, as seen from the perspective of end users, maintainers, and administrators. It describes in detail the product's key functions and features, as well as the critical interaction points and user interface.

2.1 Features & Functions

The drone has two main functions: identifying ground vehicles with ArUco markers and flying autonomously.

In order to search a field for unmanned ground vehicles, the drone will look for square-foot ArUco markers attached to the top of ground vehicles. The drone will have to fly autonomously and use a laser to attack ground vehicles once they are identified as hostile.

The drone will not need to perform obstacle detection.

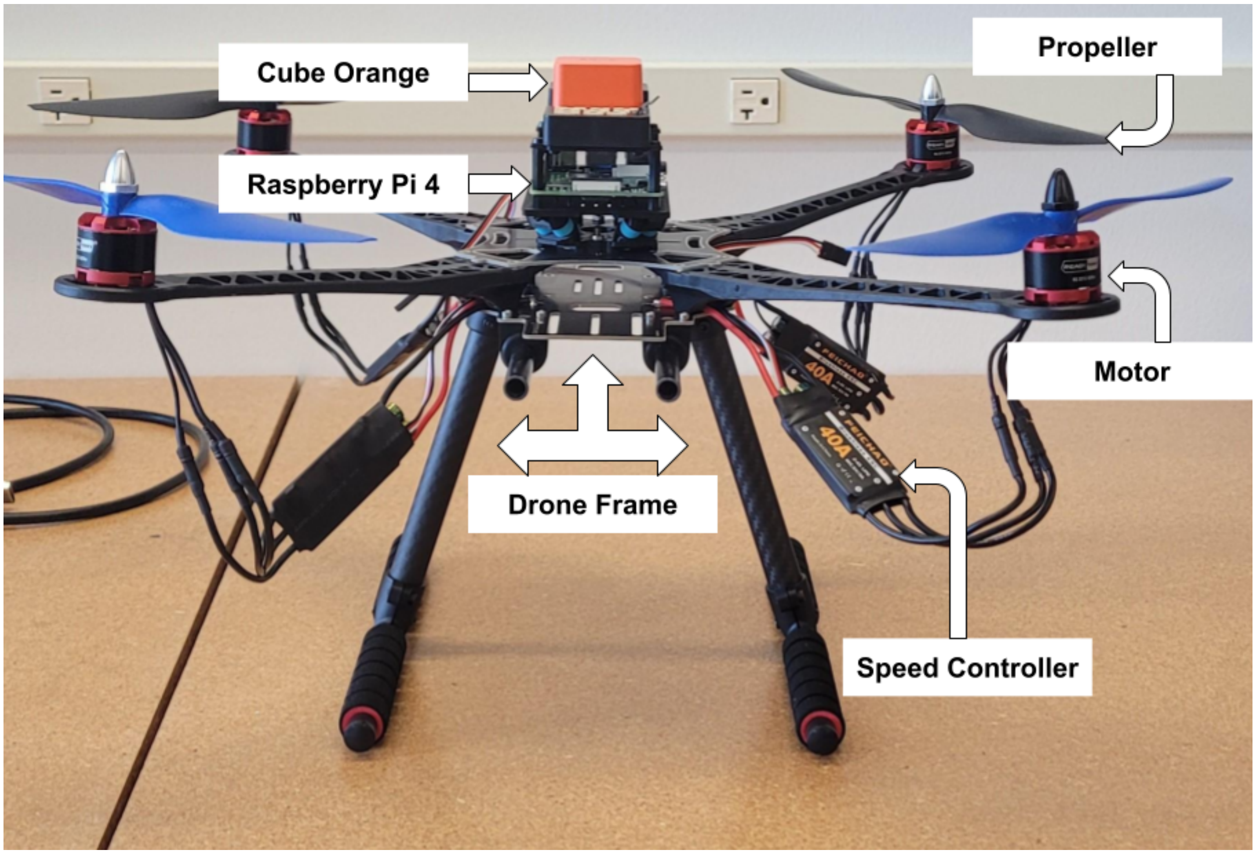

Figure 1: Image Showing The Current Build Of The Drone

A quadcopter frame will be used to build the drone. There will be four motors with propellers mounted on the frame. The drone will have two legs for landing, and a speed controller will be attached to each quadcopter arm. A 3D-printed part will reinforce the legs, making them less likely to break when landing.

The drone frame will be equipped with a mounted camera to allow it to be able to carry out image recognition functions in the future. Using OpenCV-based software, the system will be able to analyze images taken with the mounted camera. This approach will put the camera system in a position to recognize the ArUco markers places on top of every ground vehicle. A GPS and RTK sensor will also be incorporated into the drone. It will be able to locate itself with greater precision as a result of this.

2.2 External Inputs & Outputs

Name	Description	Use
GPS & RTK	It is necessary for the drone to be fed GPS and RTK information	Autonomous flight will be possible with GPS and RTK data
Off-board processing	Data from a laptop will be wirelessly transmitted to the drone instead of doing the computation on the drone with an SBC if off-board processing is allowed	The drone will be lighter since its computation can be done wirelessly from a laptop rather than an SBC like a Raspberry Pi
Camera	There will be a camera attached to a drone and connected to either a computer or a receiver that will be used to collect the data from the camera	With the use of a camera with an OpenCV algorithm, the drone can identify the ArUco markers located on the top of ground vehicles
Kill Switch	There will be a radio receiver installed on the drone to receive commands from the controller that will be used to execute the kill switch	It is necessary for the team to implement a remote kill switch to meet the requirement that a kill switch is present on the drone. By doing so they will be able to stop the drone from flying and force it to land safely
Mission Planner	Performing autonomous flight requires software such as Mission Planner to create prebuilt paths for the drone to follow to complete the task at hand	It is expected that the drone, with Mission Planner, will be able to fly autonomously along pre-made flight paths and meet all the requirements for autonomous flight.
Cube Orange	In addition to using Mission Planner, another tool that can assist in autonomous flight is a flight controller like Cube Orange	The Cube Orange will provide flight data to the drone in order to assist it in meeting its autonomy requirement, such as azimuth and height among other things

Figure 2: External Inputs & Outputs

2.3 Product Interfaces

The drone's flight paths will be planned using a program called Mission Planner. Using software like Google Maps, a satellite view of the area is displayed on the software's interface. This page allows the drone to fly autonomously based on waypoints that the user drops. A drone will follow the order of these points when it is flying, beginning with the first point and moving through to the last. A more detailed representation of the waypoints can be found under the satellite imagery. All of these columns are well organized in a spreadsheet-like table with columns for commands, latitude, longitude, altitude, distance, gradient, azimuth, and gradient relative to waypoints.

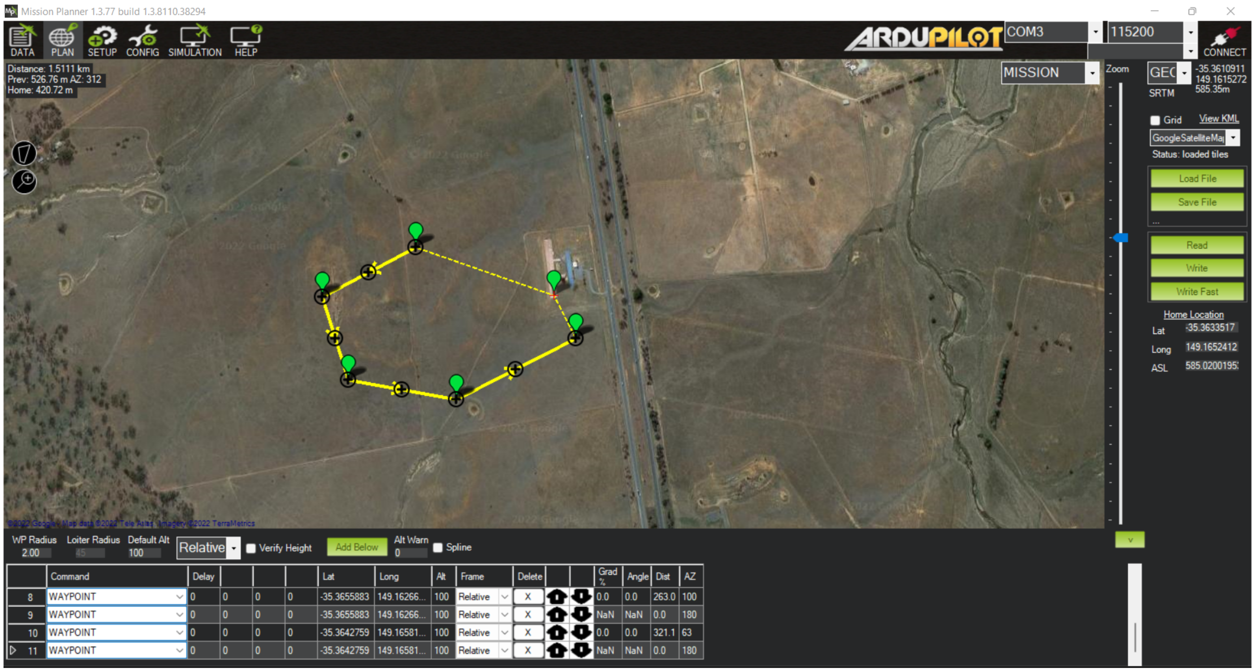

Figure 3: A view of the Mission Planner interface

3 Customer Requirements

To continue participating and being included in the 2023 Raytheon Unmanned Aircraft Systems University Innovation Showcase, the student team representing UTA must meet the requirements established by Raytheon, the project sponsor. As you will see in this section, each of the requirements listed in this section is associated with a specific demand from the project sponsor.

3.1 The Ability To Fly Autonomously

3.1.1 Description

Drones must be capable of flying autonomously and without being guided by a human driver operating them remotely as they fly.

3.1.2 Source

Raytheon.

3.1.3 Constraints

The drone must meet the standards for autonomous drone flight established by FAA regulations.

3.1.4 Standards

14 CFR Part 107 established by FAA regulations.

3.1.5 Priority

Critical.

3.2 ACE Combat System

3.2.1 Description

The drone must be equipped with the provided ACE Combat System.

3.2.2 Source

Raytheon.

3.2.3 Constraints

None other than the drone has to be equipped with the ACE Combat System.

3.2.4 Standards

Not applicable.

3.2.5 Priority

Critical.

3.3 Tracking When The Laser Is Fired With Timestamps

3.3.1 Description

It is necessary for the drone to send a software log when a laser is fired from the drone towards a ground vehicle. This software log contains the timestamp of when the laser was fired from the drone.

3.3.2 Source

Raytheon.

3.3.3 Constraints

Not applicable.

3.3.4 Standards

Not applicable.

3.3.5 Priority

Critical.

3.4 Light Up LEDs And Sound A Buzzer When Laser Is Fired

3.4.1 Description

A drone firing a laser should illuminate its LEDs and sound a buzzer to indicate that the laser has been fired.

3.4.2 Source

Raytheon.

3.4.3 Constraints

Not applicable.

3.4.4 Standards

Not applicable.

3.4.5 Priority

Critical.

3.5 At Least One Team Member is FAA Certified To Fly The Drone

3.5.1 Description

A minimum of one team member must be a licensed FAA drone pilot. All pre-flight inspections will be performed by this member of the team. He or she must pass the FAA exam. In order for the drone to fly during the showcase, a drone pilot with FAA certification must be present.

3.5.2 Source

Raytheon.

3.5.3 Constraints

The licensed drone pilot must pass the FAA drone pilot exam.

3.5.4 Standards

Not applicable.

3.5.5 Priority

Critical.

3.6 Drone Should Shoot Targets With IR Laser While Flying

3.6.1 Description

To simulate successful hits on targets, the drone should be able to fly around the field and shoot an IR beam accurately at unmanned ground vehicles.

3.6.2 Source

Raytheon.

3.6.3 Constraints

None.

3.6.4 Standards

Not applicable.

3.6.5 Priority

High.

3.7 Drone Must Have A Kill Switch

3.7.1 Description

The drone must have a kill switch. Once activated, the kill switch will cause the drone to land safely.

3.7.2 Source

Raytheon.

3.7.3 Constraints

A kill switch must be available for the CSE team to use and activate.

3.7.4 Standards

Not applicable.

3.7.5 Priority

Critical.

3.8 IR Laser Should Hit IR Receiver On Any Side Of The ArUco Markers

3.8.1 Description

While the drone is not able to pinpoint the exact location of the IR receiver, it should be able to hit the receiver on the ground vehicle.

3.8.2 Source

Raytheon.

3.8.3 Constraints

None.

3.8.4 Standards

Not applicable.

3.8.5 Priority

High.

3.9 Drone Should Use GPS & RTK

3.9.1 Description

Drones should be equipped with GPS and RTK, and the school should set up the RTK base station.

3.9.2 Source

Raytheon.

3.9.3 Constraints

None.

3.9.4 Standards

Not applicable.

3.9.5 Priority

High.

3.10 No Careless Operation And No Carriage Of Hazardous Materials

3.10.1 Description

It is never permitted to use the drone to carry hazardous materials. Drones must always be flown safely.

3.10.2 Source

Raytheon.

3.10.3 Constraints

At all times, the drone should be flown safely. It should never be programmed to behave recklessly.

3.10.4 Standards

Not applicable.

3.10.5 Priority

High.

3.11 Evidence of Drone Weight Must Be Provided Prior To Showcase Demos

3.11.1 Description

It is mandatory for the drone to comply with the weight requirement (55 lbs. max). To prove this weight has not been exceeded, the team must provide documentation to prove that the drone is in compliance with the FAA's weight restrictions.

3.11.2 Source

Raytheon and FAA.

3.11.3 Constraints

The drone must not weigh more than 55 pounds.

3.11.4 Standards

Not applicable.

3.11.5 Priority

Critical.

3.12 The Drone Must Have Propeller Guards Properly Installed While Flying

3.12.1 Description

It is mandatory for the drone to have propeller guards attached at all times while flying.

3.12.2 Source

Raytheon.

3.12.3 Constraints

Propeller guards must be present on the drone to prevent damage or injury from the propellers.

3.12.4 Standards

Not applicable.

3.12.5 Priority

Critical.

3.13 The Drone Must Fly Within A Geofence While Flying In Showcases

3.13.1 Description

To help prevent operations over anyone not participating in the event, the drone must fly within a geofence, such as within the stadium.

3.13.2 Source

Raytheon.

3.13.3 Constraints

Drone must be flown inside a geofence during showcases.

3.13.4 Standards

Not applicable.

3.13.5 Priority

Critical.

3.14 Must Verify Speed

3.14.1 Description

Students will need to have a way to verify the drone speed either by displaying it on a terminal display or some other similar tool.

3.14.2 Source

Raytheon.

3.14.3 Constraints

None.

3.14.4 Standards

Not applicable.

3.14.5 Priority

Critical.

3.15 Drone Must Be Registered With The FAA

3.15.1 Description

Students and universities must register their drones with the FAA.

3.15.2 Source

Raytheon and FAA.

3.15.3 Constraints

None.

3.15.4 Standards

Not applicable.

3.15.5 Priority

Critical.

3.16 Preflight Inspections Must Be Completed Before Showcases

3.16.1 Description

Preflight inspections must be completed to verify the drone is safe to fly and meets all rules and regulations.

3.16.2 Source

Raytheon and FAA.

3.16.3 Constraints

None.

3.16.4 Standards

Not applicable.

3.16.5 Priority

Critical.

4 Packaging Requirements

This section outlines the method and form in which the final product, as both software and hardware is delivered to the customer.

4.1 Software

4.1.1 Description

Any software for this project will be contained within a single GitHub repository. Upon the project's completion, the repository's ownership shall be transferred to Raytheon.

4.1.2 Source

https:/github.com/JaedynB/UTADroneComp

4.1.3 Constraints

None

4.1.4 Standards

Not applicable

4.1.5 Priority

Medium

4.2 Hardware

4.2.1 Description

All parts of the drone constructed by the CSE team are owned by UTA, and upon the project's completion, the drone will be given to the CSE department.

4.2.2 Source

The drone constructed by the CSE team.

4.2.3 Constraints

None

4.2.4 Standards

Not applicable

4.2.5 Priority

Medium

5 Performance Requirements

Performance requirements define how the drone should execute certain tasks under certain conditions. Software must not only be able to process instructions at a minimum efficiency, but must also be reliable and exclude any faults or bugs. The drone's hardware and frame should be able to resist impacts from crashes, as well as deal with external and environmental factors and restraints. The drone must also be designed in a way to prevent overheating. In case overheating does occur, the drone should be able to withstand the high temperatures to prevent damage to the frame or any components.

5.1 Hardware Processing Speed

5.1.1 Description

Drone must be able to run code fast enough to complete necessary tasks within a certain amount of time. Tasks include: arming drone, take off, image recognition, firing ACE Combat System laser, and autonomous navigation.

5.1.2 Source

CPU and GPU

5.1.3 Constraints

Using a single-board computer (SBC) like the Raspberry Pi 4 limits the drone's processing power. The Raspberry Pi 4 has a 1.5 GHz CPU and contains 8 GB of RAM. This should be enough to run software scripts efficiently during flight. However, off-board processing is being considered to supply the abundant processing power through a laptop computer.

5.1.4 Standards

Not applicable

5.1.5 Priority

High

5.2 Software/Firmware Efficiency

5.2.1 Description

Software written for the drone must be able to operate using algorithms that will create little or no delay between the time information is gathered (from sensors, GPS/RTK, etc.) and the time instructions based on that information are executed. No bugs should be found in the software. However, if any bugs are found, their effect on the overall system should be minimal and not detrimental.

5.2.2 Source

Source code

5.2.3 Constraints

Open source AI libraries will be used to aid software development. Some libraries may be old and not maintained so there could be limitations found in these libraries which could lead to suboptimal results in the software. This includes algorithms that may be outdated and do not run as efficiently as that which are newer. Bugs are also not uncommon in software and could be a limitation if they are not handled properly.

5.2.4 Standards

Not applicable

5.2.5 Priority

High

5.3 Setup

5.3.1 Description

Setup must be completed between competition runs. Including attaching necessary components, like the battery, booting up all software systems, and running any startup tests.

5.3.2 Source

Drone setup

5.3.3 Constraints

Time between competition runs is a boundary that will limit setup time. To be considered are also constraints regarding how fast the team can assemble drone parts, battery charge times and how many extra batteries are available, repairs and adjustments, failure to run/initialize code, and system crashes.

5.3.4 Standards

Not applicable

5.3.5 Priority

Moderate/High

5.4 Drone Frame

5.4.1 Description

The drone's chassis must be able to support the weight of all hardware components. The frame must also withstand substantial damage from crashes and stress generated when landing. When landing, most of the stress will be in the legs. Leg reinforcements will be made to help with this. The arms must be firm enough to hold the motors when on the ground, as well as strong enough to hold up the center of the body when in the air.

5.4.2 Source

Drone frame (especially frame's arms and legs)

5.4.3 Constraints

The weight of components is significant and too much weight could cause great tension in the arms and legs of the drone. Having heavy motors can weigh down on the arms when the drone is stationary and a heavy center (SBC, flight controller, battery, etc.) while it is airborne. The leg's design could allow for them to break easily if the drone does not land properly. Crashes could limit the frame's ability to perform correctly. Damages during crashes can weaken the frame and make it easier to break in future crashes or during flight.

5.4.4 Standards

Not applicable

5.4.5 Priority

Moderate/High

5.5 Autonomous Flight

5.5.1 Description

Drone must be able to fly autonomously using GPS/RTK and sensors. Open source AI libraries will be used for autonomous flight. The drone should be programmed with flexibility in items such as start and end locations and flight duration. No input from a pilot should be given to the drone after takeoff unless there's an instance in which safety is hindered. In this case, the pilot must use a kill switch or manually override the drone to land it safely.

5.5.2 Source

Artificial intelligence libraries

5.5.3 Constraints

As mentioned in the software/firmware efficiency requirement, open source libraries may be deprecated, not maintained, or not efficient. Faulty hardware such as GPS/RTK, optical flow sensors, and LiDAR sensors could lead to inaccurate measurements of information and directly affect autonomous flight.

5.5.4 Standards

Not applicable

5.5.5 Priority

Critical

5.6 Battery

5.6.1 Description

The battery life should be light and able to output enough power for the motors, speed controllers, GPS/RTK, sensors, flight controller, and SBC. Its life must endure the duration of the competition run and should charge at a fast enough speed that would not obstruct competition performance.

5.6.2 Source

Battery

5.6.3 Constraints

Size of battery is the main factor constraining this requirement. Larger batteries tend to have more power but also weigh more and have longer charge times.

5.6.4 Standards

Not applicable

5.6.5 Priority

Critical

5.7 Flight Controller

5.7.1 Description

The flight controller must be able to accurately read data from attached and internal components and process calculations based on the information. It should also be able to communicate with the SBC (or off-board computer if used).

5.7.2 Source

Flight controller

5.7.3 Constraints

The firmware installed on the flight controller may contain bugs that have not been fixed. Internal components and sensors (IMU, barometer, magnetometer) may also not provide accurate readings.

5.7.4 Standards

Not applicable

5.7.5 Priority

Critical

5.8 GPS & RTK

5.8.1 Description

GPS and RTK must be able to connect to satellites to determine the drone's global position and an RTK base station to fine tune its position.

5.8.2 Source

GPS/RTK

5.8.3 Constraints

The wireless connection between the GPS/RTK system and satellites may be interfered with, along with the connection to the base station.

5.8.4 Standards

Not applicable

5.8.5 Priority

Critical

5.9 ACE Combat System & Camera w/ Gimbal

5.9.1 Description

The camera, gimbal, and ACE Combat System must work in unison to disable targets. The camera gimbal must be able to move when necessary, depending on the image recognition algorithms, to help the camera identify targets. When a target is spotted, the ACE Combat System must shoot its laser towards it to disable it. When the laser is fired, the drone must light up, sound a buzzer, and log the event via software logs (including a timestamp).

5.9.2 Source

ACE Combat System, camera, and camera gimbal. Some of these requirements were derived from the statement of work given by the sponsor.

5.9.3 Constraints

Constraints for the camera include image resolution, image distortion from lens, and battery life. The gimbal may not move properly if the camera is too large or heavy. As for the ACE Combat System, the laser's strength, accuracy, and precision could affect performance when attempting to disable targets.

5.9.4 Standards

Not applicable

5.9.5 Priority

Critical

5.10 Optical Flow Sensor w/ LiDAR Sensor

5.10.1 Description

An optical flow sensor and LiDAR will be used in the event of the competition needing to be held indoors. The optical flow must work properly to help determine the position of the drone relative to its start position. The LiDAR will be used to determine the height of the drone and will work with the optical flow sensor to help find the drone's position.

5.10.2 Source

Optical flow sensor and LiDAR sensor

5.10.3 Constraints

The optical flow sensor may be susceptible to lighting.

5.10.4 Standards

Not applicable

5.10.5 Priority

Critical

5.11 Motors

5.11.1 Description

Motors must be light and capable of generating enough lift for the drone to fly.

5.11.2 Source

Motor

5.11.3 Constraints

More powerful motors tend to be larger.

5.11.4 Standards

Not applicable

5.11.5 Priority

Critical

5.12 Showcases

5.12.1 Description

There will be four showcases which each contain varying requirements. The drone must complete the tasks for each showcase under the given time.

5.12.2 Source

Statement of work given by the sponsor

5.12.3 Constraints

Each showcase is different and has different tasks meaning different software solutions will need to be developed.

5.12.4 Standards

Not applicable

5.12.5 Priority

Critical

6 Safety Requirements

This section will define constraints, in both software and hardware, implemented on the drone to prevent unwanted and potentially dangerous incidents. Also included are processes used to approach development.

6.1 Laboratory Equipment Lockout/Tagout (LOTO) Procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Critical

6.2 Other Lab Safety Procedures

6.2.1 Description

Lab tools and equipment such as cutting tools and soldering stations must be handled with care and used only with appropriate safety equipment such as goggles, gloves, fume extractors, etc. All lab policies must be followed. Caution must also be applied when testing and handling certain drone components. The battery should be handled with care as misuse could lead to not only damages to the battery and vehicle but also serious injuries to the one handling it. When testing the drone indoors, the drone should be tied down and/or the propellers must be removed to avoid any injuries and damages to the drone. The ACE Combat System laser should also be handled with care and not aimed at eyes.

6.2.2 Source

CSE Senior Design laboratory policy and safety precautions

6.2.3 Constraints

Constraints

6.2.4 Standards

Not applicable

6.2.5 Priority

Critical

6.3 Manual Override

6.3.1 Description

The drone requires a "kill switch" that will override the drone's flight mission and land the drone safely and/or allow manual override.

6.3.2 Source

Statement of work given by the sponsor

6.3.3 Constraints

When the "kill switch" is activated, the drone must still be landed safely.

6.3.4 Standards

Not applicable

6.3.5 Priority

Critical

7 Security Requirements

There are a few security risks to be considered when working on a project like this one. As this project is being developed for a customer that is a part of the DoD it is especially important to consider them and find ways to take actions to protect against vulnerabilities. This section explains potential security measures that could be taken to be more secure.

8 Maintenance & Support Requirements

This section highlights how the drone hardware and software should be ideally maintained. There are a few moving pieces as well as open wired connections in that drone that are sensitive in some conditions. Many issues can occur on the software or hardware side of things or both. A person with a technical background in software or hardware will be best to attempt unplanned maintenance (e.g. a component failure or human error). For routine maintenance, the person does not need to be technical.

8.1 Routine Maintenance

8.1.1 Description

This will include visual inspection of moving parts, inspection of all wiring, cleaning debris or dirt after each flight, run performance test for the batteries, update software and drivers, and check for any damages to key component. Having a routine maintenance check will reduce the risk of crashes and save the team money in the long run.

8.1.2 Source

Fortress UAV.

8.1.3 Constraints

None

8.1.4 Standards

It is expected that each inspection meets the industry standard.

8.1.5 Priority

Low

8.2 Record Keeping

8.2.1 Description

This will include keeping a record of each test flight that the team runs and the team members that ran the test. It will also include version control for the software that is written for the UAV. A record of routine maintenance will be kept tracking any issues, when they were discovered and also keep track of replaced parts. This will be done to reduce the time it will take to identify/narrow the causes of issues.

8.2.2 Source

Public Sadtey Flight.

8.2.3 Constraints

None

8.2.4 Standards

Records will be ordered in chronological order.

8.2.5 Priority

Medium

9 Other Requirements

This section will provide all necessary documentation. Teams must follow the FAA UAV Requirements prior to demonstrations.

9.1 Requirement Name Certification

The team Top Drone Maverick will need a student to obtain his FAA UAV pilot certification. According to Raytheon, a student must become FAA certified as a requirement for the competition.

9.1.1 Source

Federal Aviation Administration

9.1.2 Constraints

The student would have a minimum of 14 days before he could retake the FAA exam.

9.1.3 Standards

To receive your FAA Pilot Certifications, you must pass the exam with a grade of 70% or above.

9.1.4 Priority

Critical

10 Future Items

In this last section, you will reiterate all requirements that are listed as priority 5. This is repetitive, but necessary as a concise statement of features/functions that were considered/discussed and documented herein, but will NOT be addressed in the prototype version of the product due to constraints of budget, time, skills, technology, feasibility analysis, etc. Use the following format for this section.

10.1 N/A

For our project future items wouldnât be required. Raytheon has a Submission deadline, and also has competition that occurs April 2023.

10.1.1 Source

Team Idea

10.1.2 Constraints

Competition deadline

10.1.3 Standards

N/A

10.1.4 Priority

Low

11 References