UAV Drone Replenishment: Milestone Report

ADCS Dynamics

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MVP and Milestone Status

Over the last couple of weeks, we have reframed our project and gained a better understanding of the expectations that Professor Jack Silberman and the rest of Triton AI have for us. In our Project Specification, we laid out a development plan that iterated on simulator development. However, while working with members of Triton AI, we've found that their development plan prefers physical testing over the simulated alternative. This renders our previous MVP goal of a fully-functioning simulator development less desirable. Therefore, we have decided to pivot our MVP for this project to developing the software that enables our drone to autonomously take off from the boat and safely land on the landing pad. It is important to note that this is not a less-complicated MVP in comparison to our previous plan, but rather, a shift to better meet the expectations of our leads at Triton AI.

Addressing Feedback

1. Progress seems a little slow compared to other projects.
   - Our main limiting factor was the drone build, where the combination of hardware issues and weekly offsite lab sessions hindered our progress. We have now completed the drone build, and have established communications with our team leads to relocate the drone to campus during the week for an additional lab session each week. We expect an increase in the rate of progress given these reliefs.
2. Make sure to work closely with Triton AI team. Last year there was some problems due to lack of equipment and changing focus at the end of the quarter.
   - Our team leads at Triton AI have been very communicative and helpful with their guidance throughout this process. They have also been quick to provide us with necessary hardware materials. We expect their continued support to remain consistently helpful as we near the end of the quarter.
3. I really want to see a hard push at the end here to meet your goals as some screenshots of the tin cups on a background that is very different from the competition with a camera that is entirely different from the one being used by the drone is a massive red flag.
   - To establish a reliable development environment and gain familiarity with tools and technologies that are novel to us, we decided to use images taken from an iPhone camera against a concrete background as a sample dataset to create and test run an initial YOLO model for learning purposes. We acknowledge this method deviates from standard practice, and therefore have had plans to replace our sample dataset with photos taken by the Arducam drone camera, and against a competition-accurate background. Given our successful drone flight, we are now able to utilize the Arducam drone camera from varying heights and angles for our new dataset. Additionally, our previous contact was recently unable to acquire a print for our landing pad (2m x 2m), and thus we are pursuing alternative options (Triton Print).

Group Management

Our team has divided into two subdivisions in order to effectively split up project tasks.

Hardware team

Alec and Daniel have been developing on the autonomous drone flight software side of the project. Alec is focusing on running the SITL Simulator and simulating tested drone flights, while Daniel is working with the Jetson Nano, setting up the ROS2 Humble environment and deploying our YOLO model. Additionally, Alec and Daniel are co-developing the integration between the Jetson Nano and the Pixhawk flight controller, designing the software architecture that will be used to perform sensor fusion. For the future, they will continue testing and refining the autonomous drone software on the SITL Simulator, deploying and testing the YOLO models and OpenCV algorithms on the Jetson Nano, and integrating the drone software and hardware components to ensure correct and accurate use of the various cameras and sensors on the drone.

Software team

Soumi and Carson have primarily been focusing on the object detection and software tasks. Carson led the dataset collection effort to train our computer vision model which included annotation, preprocessing and augmenting the data while Soumi developed and trained the YOLO model using the collected dataset, deployed it and experimented with other OpenCV algorithms to explore all possible avenues. For the future, they will attempt to expand the dataset using images captured from the flying drone using the Arducam and also train a new model for landing pad detection. Moreover, they will also explore a less computationally expensive OpenCV algorithm as a back-up in case the Jetson Nano is unable to process the video stream at the expected speed.

All team members have been sufficiently present during offsite Inspiration Lab sessions on Saturdays, resulting in a successful drone build which has also successfully passed an initial flight test during our most recent meeting. Alec and Daniel finalized the drone assembly and performed the first successful flight test, marking one major milestone for our project. Soumi and Carson developed the initial CV model for detecting the target tin cans, marking a second major accomplishment.

Note: Members who are unable to attend on any particular Saturday continue software development remotely to ensure effective use of time. So far, all project members have attended the majority of offsite lab sessions.

Contributor	Contributions
Alec	Drone build and calibration, SITL Simulator drone flight testing
Daniel	Drone build, ROS2 Humble Docker setup, single-image YOLO deployment on Jetson Nano
Carson	Drone build, curated and annotated images for dataset, helped with CV models
Soumi	Drone build, built OpenCV model, trained and created YOLO pipeline

Table 1: Past Contributions

Contributor	Future Contributions
Alec	ROS2 autonomous control algorithms, Jetson Nano and Pixhawk integration
Daniel	Live multiple-image deployment on Jetson Nano, Jetson Nano and Pixhawk integration
Carson	Dataset curation 2.0 (ArduCam), combining models for landing pad and tin can detection
Soumi	YOLO model with live video feed, OpenCV feature detector (as backup)

Table 2: Future contributions

Weeks	Alec	Daniel	Carson	Soumi
Week 7	SITL Simulator	YOLO Integration	Helipad dataset	Train YOLO (helipad)
Week 8	Landing Sequence	Flight Integration	Helipad model	ArduCam + YOLO
Week 9	Tune ROS	Tune ROS	Tune OpenCV	Tune YOLO
Week 10	Tuning	Final Report	Final Report	Tuning

Table 3: Detailed future contributions by week

MVP Completion

For our initial MVP, we had set our goal to be the successful operation of the drone in the SITL Simulator, with metrics for success determined by the UAV Replenishment task outlined by RobotNation's RobotX Maritime Challenge 2024 citeRoboNation2022.

During an offsite Inspiration Lab session on May 4, we spoke with our team leads at Triton AI regarding the progress of our project and future goals, after having made significant progress on our drone build. Our leads explained that Professor Jack Silberman expected tangible deliverables, rather than a simulation.

Therefore, our team shifted the focus of our MVP to match that of Triton AI. Our updated MVP is the successful autonomous launch of the drone and land on the UAV Replenishment landing pad. Stretch goals for our project will be to improve the accuracy of our model and autonomous flight software to be able to align the manipulator with the tin can, and successfully pick up the tin can for relocation.

Roadblocks

Hardware Issues

Our project progress has been hindered by several hardware complications, which although now resolved, have marked a noticeable dent in available time. Additionally, a significant impediment to our progress has been the offsite lab sessions, which have so far only enabled us to further our progress on Saturdays, when our team leads are most available to guide our construction and support debugging technical issues.

Software Issues

Moreover, we also ran into computing resource-related issues when training the YOLO model. Soumi initially attempted training on her local machine and on Google Colab, which took over 7 hours before both machines crashed. We then switched to Datahub where we trained the initial version of our model and deployed the model weights. We recently got access to the Kastner-ML machine as well and we're in the process of setting up a training pipeline on it.

However, we have now successfully performed an initial manual flight test, with the drone operating as expected. We have also communicated with our team leads to relocate the drone to the on campus Triton AI lab during the week. This will allow us to work with the drone hardware twice each week, doubling our allotted time. Given the drone build is now complete, this removes our main roadblock as it allows us to further pursue both our autonomous flight software, as well as our OpenCV algorithms, as we can now test our software on the drone for real-time experimentation and analysis.

We are now in a better position for our project, as the removal of limiting factors has opened up our paths for software development. We will continue our progress towards our reestablished MVP, building our software stack and iteratively testing it on the drone to identify areas for refinement.

Milestone Completion

We have reached two major milestones of this project, as aligned below.

Drone Build

The first milestone is the completion of the build of the drone. Specifically, we were able to assemble the drone and complete its first test flight (Figure 1). While some minor hardware tasks still need to be completed, the ability to fly the drone allows us to continue onto other milestones that were dependent on this milestone. Namely, we will be able to build a dataset for our YOLO and OpenCV models by taking pictures from the drone that are more representative of the competition environment.

(a) Built drone with controller

(b) Drone in first test flight

Figure 1: Milestone: Drone Build

Object Detection Model

This leads to the second milestone we have completed, the initial CV model for detecting our target tins (Figure 2). The initial model is a YOLOv5 model trained on our initial test dataset of our target tins. The model is able to accurately detect the position of our target tins in images taken from a smartphone. While this dataset may not accurately represent the images taken from the drone, it was a major achievement because collecting the dataset, preprocessing, annotating, and augmenting the collected images was a long process that took us time to fully understand. Thus, this first model helped us define the workflow we'll be using for the remaining weeks to finish up our dataset.

While the completion of this milestone is significant, we will be refining this model by creating a dataset with the drone's camera (ArduCam), retraining the model and testing it in a representative environment. This milestone allows us to start developing our control software to be able to land on the helipad.

(a) Sample training image from our dataset (b) YOLO detecting the targets on a test image

Figure 2: Milestone: Object Detection

Future Milestones

Our future milestone follow our development procedure to obtain our MVP by the end of the quarter. For our object detection models, the main task is to deploy the model onto the Jetson Nano. On top of deploying the model, it will be necessary to refine the model such that it can perform the object recognition task fast enough such that our control loop can accurately land on the helipad. Moreover, we currently only have a model to detect the colored tin cans. We also aim to build a model to detect the helipad. Soumi will be training the YOLO model for recognizing the helipad and exploring an alternative OpenCV algorithm as a back up, while Carson will assist with curating the helipad dataset and finalizing the computer vision pipeline. Daniel will also be supporting the YOLO model deployment onto the Jetson Nano.

On the control software side, our next milestone is to test the helipad landing sequence in a simulator before then moving on to testing it in our actual drone. Once we have completed this milestone, which is also our MVP, we will then move on to attempting the object manipulation goal of this project. If we can land accurately enough, then we should be able to land close enough that our object manipulator can pick up our target cans. After success with the simulator, we will integrate the Jetson Nano with the Pixhawk flight controller to enable physical flight testing. Alec and Daniel will be working on this milestone together.

For a more detailed breakdown of the individual contributions of each team member, please refer to the planned contributions outlined in Table 1, the future contributions in Table 2, and the detailed weekly breakdown in Table 3.

Rest of Quarter Timeline

Our milestone progress follows the schedule of our gantt chart found in Figure 3. We are marginally behind on tasks, but are better equipped to catch up now that we are able to work with hardware outside of solely just the weekend lab visits.

For a more detailed breakdown of the individual contributions of each team member, please refer to the planned contributions outlined in Table 1, the future contributions in Table 2, and the detailed weekly breakdown in Table 3.

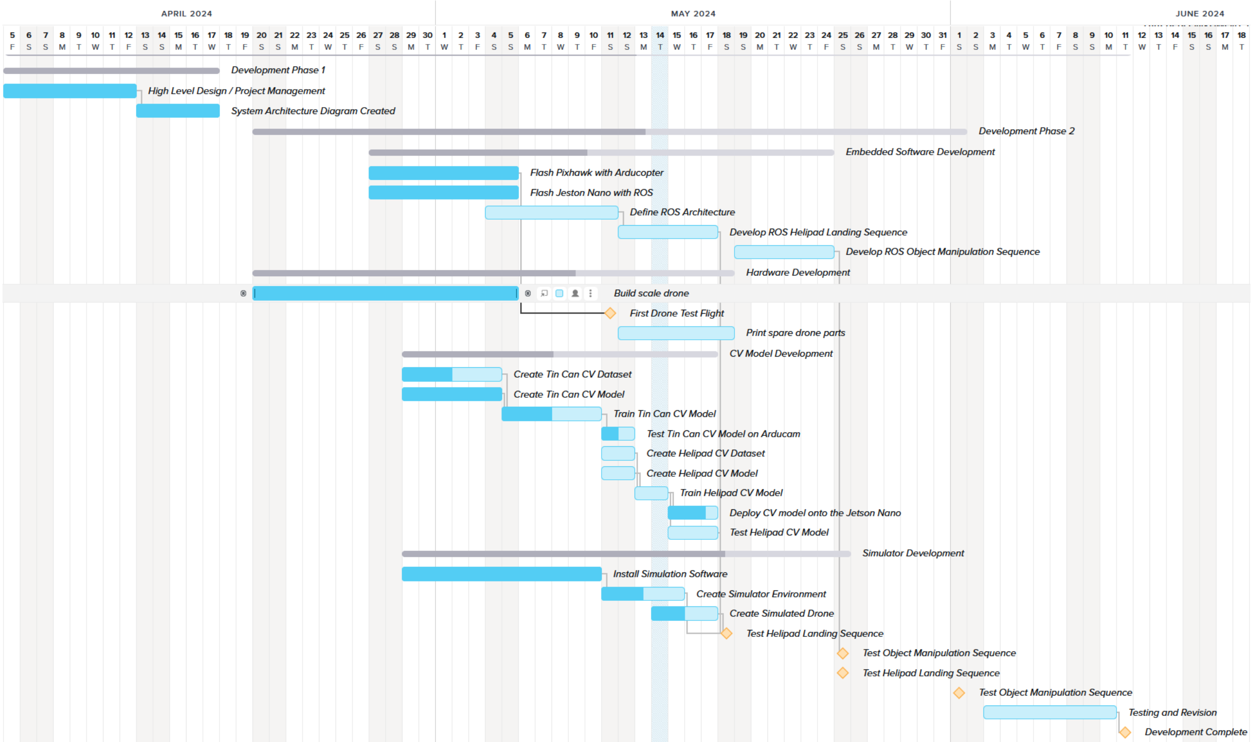

Figure 3: The gantt chart outlying the schedule for our project.

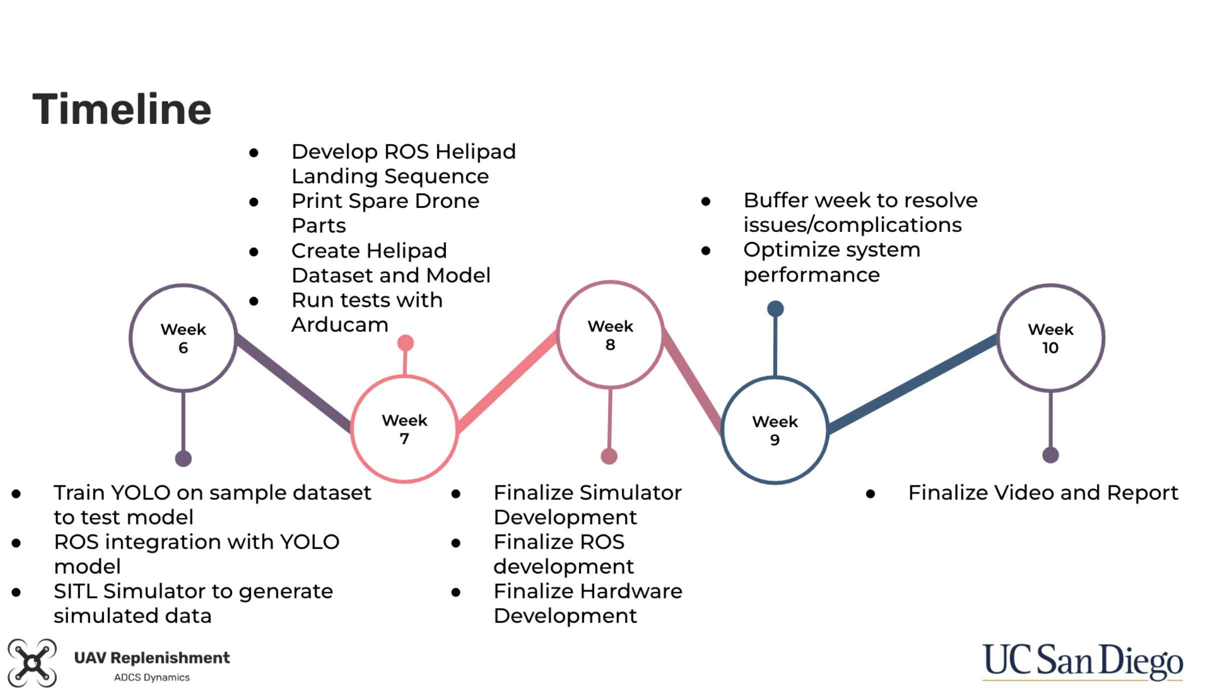

Figure 4: The timeline of tasks laid out

References

[1] RoboNation, “2022 RobotX Team Handbook,” 2024. [Online]. Available: https://robonation.org/app/uploads/sites/2/2022/03/2022-RobotX_Team-Handbook_v2.pdf. [Accessed: 19-Apr-2024].