Drone Performance Tracker User Manual

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1 Introduction

The Introduction section explains the system and the purpose for which it is intended.

The information included here will instruct the user on how to set up the hardware and utilize the software for tracking a drone flight and measuring performance. The user targeted for this manual is the flight instructor of the drone pilot whose performance is to be assessed.

This system is designed to track a sUAS ("small Unmanned Aircraft System") in a 15 meter long by 15 meter wide by 10 meter tall volume of space using two smartphone cameras. The goal of the system is to show the sUAS's flight path digitally on a 3D graph on the User Interface, as well as display the change in velocity between the logged points on the plot. This information will be used by the flight instructor to assess the performance of the sUAS pilot.

2 Getting Started

The Getting Started section explains how to set up the hardware and software so that performance analysis is ready to commence.

2.1 Software Setup

2.1.1 Flight App Installation

In order to install the flight app, several things must be installed first. They are listed below in order:

1. Python 3.7
2. Pip3
3. MatPlotLib
4. PyQt5
5. Numpy

First, download Pyenv. This can be done by installing Homebrew (for MacOS) computers. Instructions for installing Homebrew can be found here: `https://brew.sh/`. Once Homebrew has been installed, run `brew install pyenv` in the terminal. Now Python can be installed by running `pyenv install python3.7` in the terminal. This will install Python 3.7 and you can set this as the default version of Python on your system by running `pyenv global 3.7.x` (the x will be the specific version of Python 3.7 you've installed. Now you have Python 3.7!

Next, you need to install the specific Python packages that the Flight application depends on, MatPlotLib, PyQt5 and Numpy. All 3 of these applications can be install by going to the terminal and running `pip3 install <package>`. For example, to install Numpy, simply run `pip3 install numpy`. Use pip3 to install all of the packages and you can now run the Drone Tracker application!

Now to install the Drone Tracker application, go to the Github website where the application is located. The url for the site is here: `https://github.com/JonathanGWesterfield/Capstone`. Download the repository by clicking the "Clone or Download" button and then clicking the "Download ZIP" button. You can also find the latest stable version of the program by going to the releases page and downloading the latest stable release. Unzip the folder once it has been downloaded. To start up the application, refer to section 2.1.3.

The program was created on a Mac computer so use of a Mac is preferred, though the program should be compatible on any operating system.

2.1.2 Camera App Installation

The application of the Camera App is a little trickier than the Drone Tracker Flight app. A number of steps must be taken care of before the application can be run on a phone. Follow the steps below.

For the steps to be done on the computer:

1. Install Java 1.8.
2. Install the Android SDK.
3. Install Android Studio.
4. Open the Camera2 project located in the Camera2 folder using Android Studio.
5. Allow the Gradle project to load and build.
6. App is now ready to be installed on the phone!

For the steps to be done on each phone:

1. Go to settings and enable developer options (this changes depending on the version of Android on the phone. Look it up to find the correct way).
2. Go to Developer Options and enable USB Debugging.
3. Once the phone connects to the computer, hit the "Trust" button so the phone will allow downloads from the computer.
4. The phone is now ready to have an application installed on it!

Once the previous steps have succeeded, connect the phone to the computer again while the Camera2 project is loaded in Android Studio. Make sure that your phone is the target to run against and click the Play button in the upper right hand corner. This will install the application onto the phone and run the app. Unplug the phone from the laptop. The phone is ready to be run!

2.1.3 How to Run The User Interface

Once the Drone Tracker app has been downloaded from the Github repository, open up the terminal (or command line) and navigate to the `Flight-App-Exe/Flight-App` directory and locate the `Program_Controller.py` file. To start the application, simply run `python3 Program_Controller.py`. If everything has been installed correctly, the user interface application will start right up!

2.2 Hardware Setup

2.2.1 Hardware Materials

The user should first secure all the necessary hardware materials, as shown below in Figure 1.

Figure 1: Supplies

The hardware materials are as follows:

- Three 100-ft extension cords
- Power strip
- Router with power cord
- Four sets of two stakes to measure out space
- Two sets of two stakes to measure phone distance
- Two 75-degree angle phone stands
- Two Android phones with application installed
- Two compatible phone chargers
- Laptop with software installed
- Laptop power cable
- Four cones (optional)

2.2.2 Measure Out The Flight Area

First, the user should mark out the 15 by 15 meter square in which the drone will be tracked by using the 4 provided sets of 2 wooden stakes connected with twine. This is shown in Figure 2.

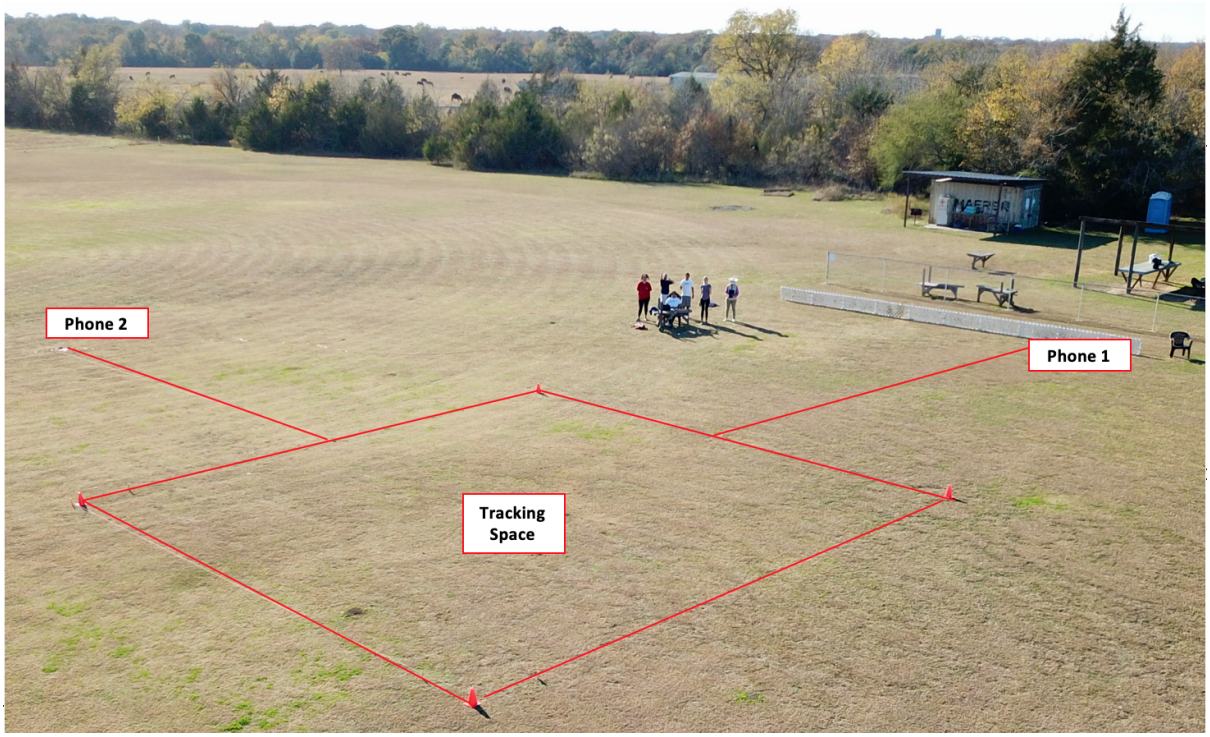

Figure 2: Overhead set up

Next, the user should place the 2 additional sets of stakes marked "Phone" in the configuration shown in Figure 2. These stakes denote where the phones will be placed, as explained further in section 2.2.3.

2.2.3 Proper Setup and Positioning of the Phones

The two phones used to track the drone are set up on perpendicular sides of the tracking area. One phone will track the x/z coordinate plane of the tracking area, while the second will track the y/z coordinate plane. The phones need to be placed 16.8 meters away from the center of the sides of the tracking area, as shown in Figure 2, in order to have the entire tracking space in view of the camera.

Once the phone distances have been confirmed, you must follow the steps in section 2.2.6 (opening the mobile application and entering in computer credentials) before proceeding with the rest of this section. Once the computer credentials have been entered into the app, place the phones onto their 75 degree angle phone stands on a level surface, with the phone facing the field and the camera positioned on the right side. Ensure that the entire tracking area is within the frame of the video feed shown on the app. Carefully position the center of the frame on the center of the field, with an equal amount of

distance between the closest cones and the edge of the picture. This is shown in Figure 3.

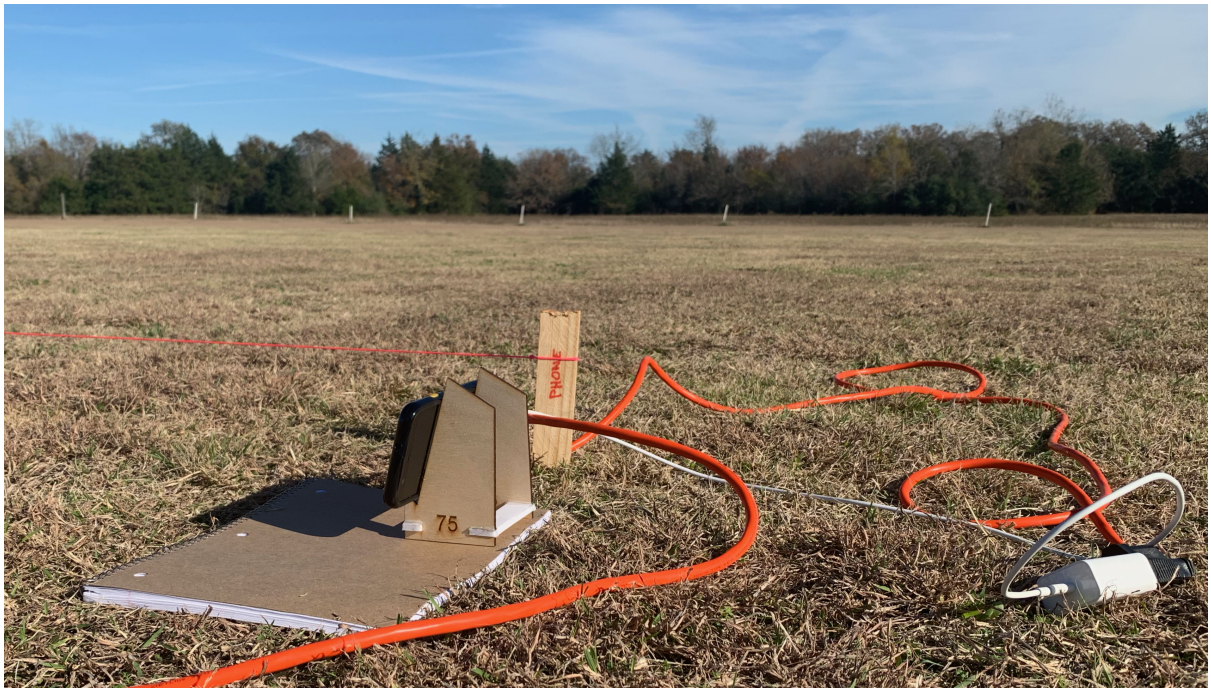

Figure 3: Phones set up

2.2.4 Connecting the Power Supply

It is imperative that power is provided to all devices, as the the operation of this setup cannot proceed for more than one or two flight tests before the individual parts will start to die otherwise. To solve this problem, run extension cord(s) from the power supply source to a power strip, set up near the router. Plug into the power strip the following parts: the computer running the software, the router, and 2 extension cords. This is shown below in Figure 4.

Figure 4: Power Set Up

Run the extension cords from the power strip to the phones, and plug the phone power cords from the extension cord into each phone. This will allow the phone to run for as many flights as wanted.

2.2.5 Optimal Positioning of the Router

The router is the biggest bottleneck of the operation, and as such its optimal placement is crucial in reducing footage transfer time. The best place to put it is as close to the midpoint between the phones as possible as well as near the computer so all of the devices have the strongest connection possible. The computer can, however, be used at a greater distance than the phones can due to its ability to use an Ethernet cable; however using one is more of a recommendation than a requirement and is up to the user.

For ideal set up, place the router and the laptop on a table near the power strip, positioned equal distance between the two phones along the diagonal. This is shown in Figure 5.

Figure 5: Table Set Up

2.2.6 Ensuring the Phones Are Ready to Connect

Once the router is set up, and power has been run to all of the devices, be sure that the phones and laptop are connected to the same Wifi connection.
Unfortunately, a common issue may complicate this a bit, as after connecting the phones to the router, they will opt to not use their Wi-Fi connection as there is no internet, only a local connection. This can be easily remedied by going into the Wi-Fi settings on the phones and selecting the option to use the network even though there is no external connection.
You may now need to refer back to section 2.2.3 in order to ensure that the framing of the cameras on the phones is correct.

2.3 Sync The Phones to the User Interface

These steps are to be completed once you have navigated to the Verify Set Up screen on the user interface, which is discussed further in section 3.2.

To connect the phones to the user interface, find the IP address of the computer the user interface is running on. To do this for MacOS, go to System Preferences, then to the Network page. For Windows, open the command line and type `ipconfig /all`. Then

make sure that port 8000 is open by checking your network settings (this port should already be open in MacOS).
To sync both phones to the user interface, simply open the user interface, navigate to the Verify Setup Screen by pressing the 'Verify Setup' button on the Home Screen (discussed further in section 3.2) and click the sync button. Once this button has been pressed, go to each phone and start the Camera2Video app. You will be directed to the screen seen in Figure 6 below. Input the IP address of the laptop, port 8000, and the username and password of the currently logged in user of the laptop. Once all of the information is entered, click the 'Connect' button at the bottom of the phone screen.

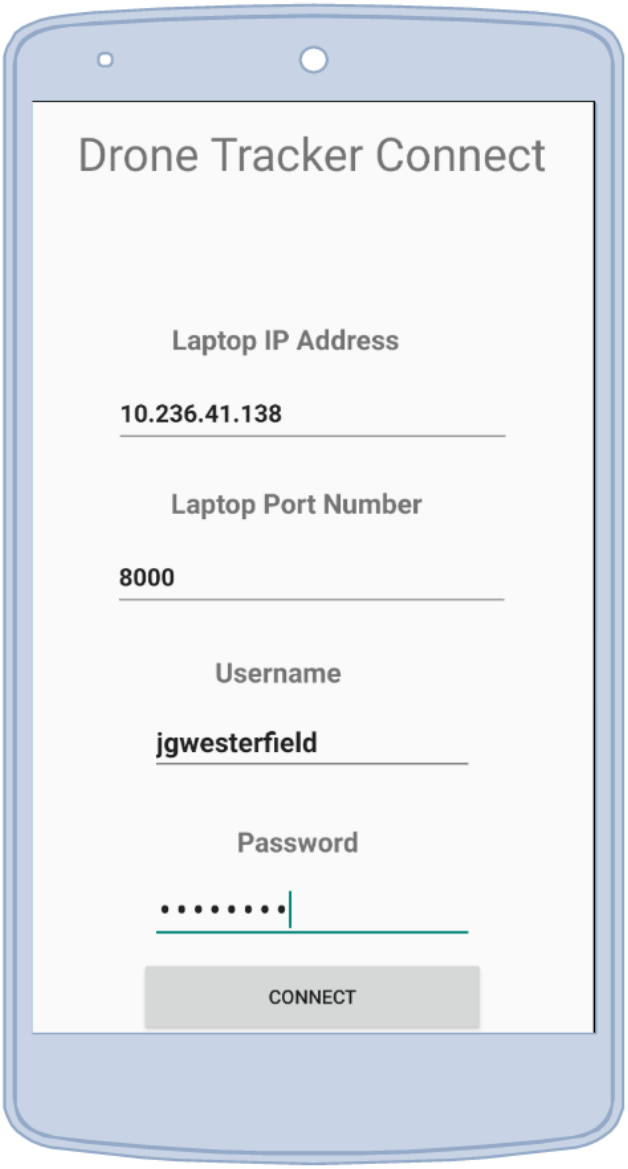

Figure 6: Mobile Application

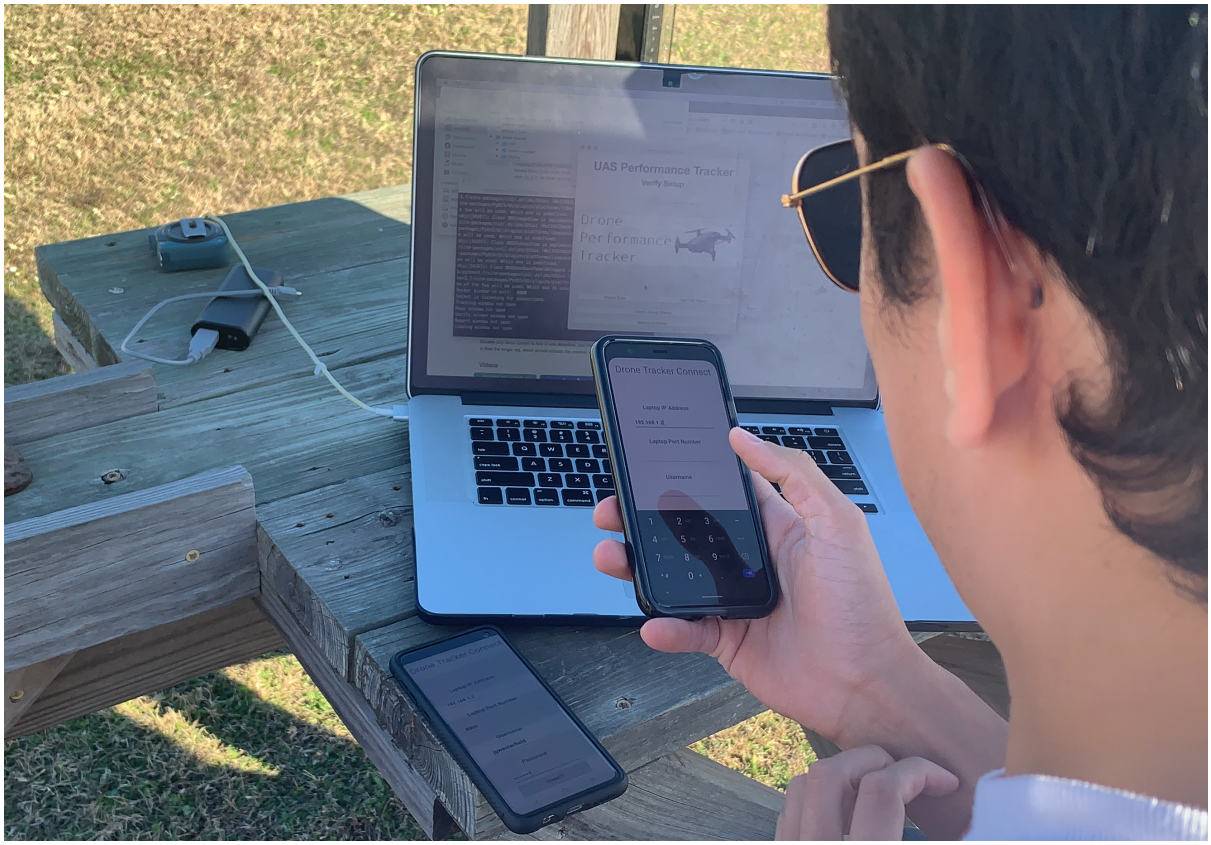

Figure 7: Information being entered into the applications

Once both phones have established their connections, the Flight app on the laptop will then display they the sync was successful, and the phones will display the screen in Figure 8.

Figure 8: App once Connected

3 User Interface

3.1 Home Screen

The Home Screen is displayed on system launch and is the main hub for the user interface. As shown in Figure 9, this screen contains 3 buttons for the user to interact with: 'Verify Set Up', 'Start Tracking', and 'Import Previous Flight'.

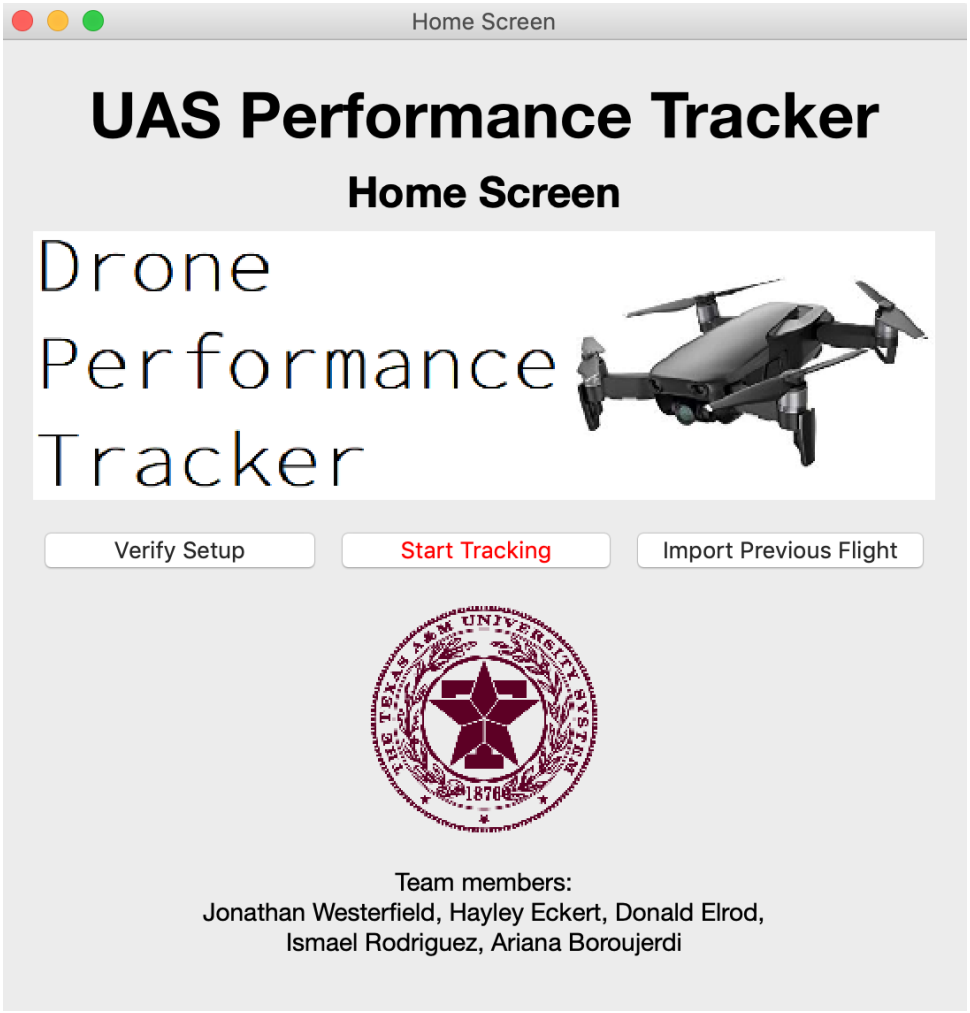

Figure 9: Home Screen

If the user wishes to track a new drone flight and analyze the results, the user must first push the 'Verify Set Up' button. This transitions the user to the Verify Set Up Screen discussed in Section 3.2 and allows the user to test the hardware configuration before initiating the drone tracking capability of the system. Until the user goes through the steps within the Verify Set Up screen, the button labeled 'Start Tracking' will not be enabled on the home screen and will be grayed out for visual effect.

If the user wishes to import a previous flight report for viewing, he or she can press

the ‘Import Previous Flight’ button then select a file for importing. After selecting a file to import as shown in Figure 10, the user will be taken to the Flight Report screen to view the results.

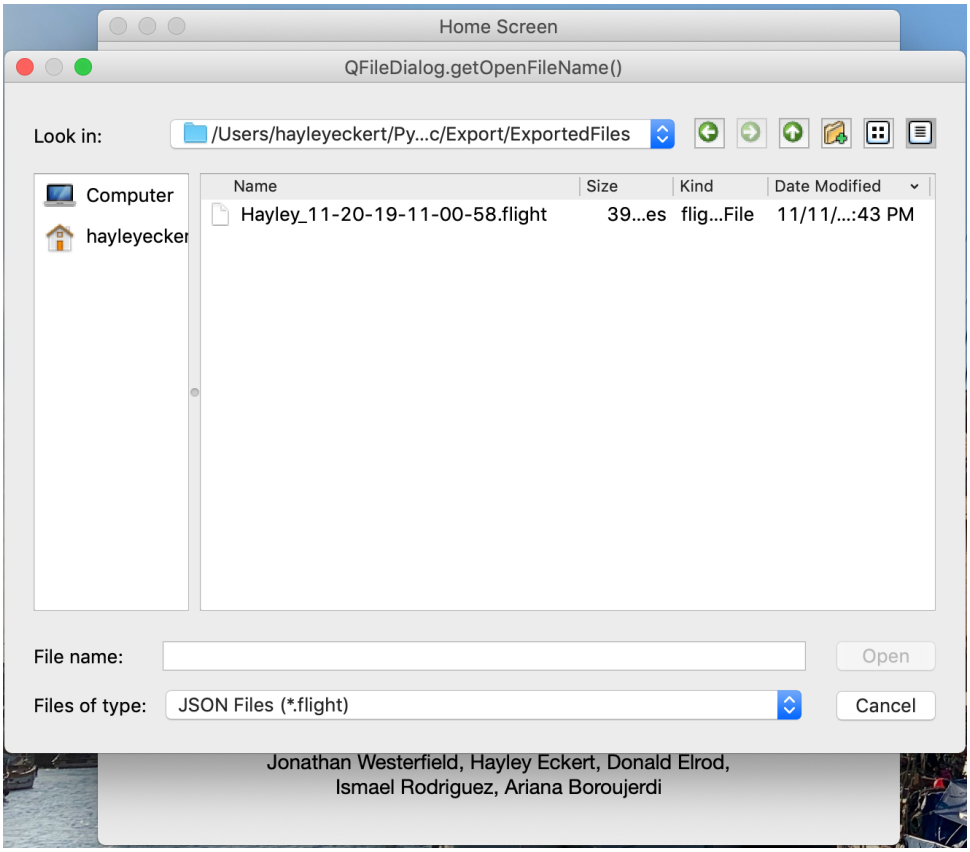

Figure 10: Import Previous Flight

3.2 Verify Setup Screen

In this screen, the user is able to verify that the system has been configured properly in order to allow a drone to be tracked successfully. This screen contains two key buttons: ‘Test Phone Setup’ and ‘Test Full Setup’, as shown in Figure 11.

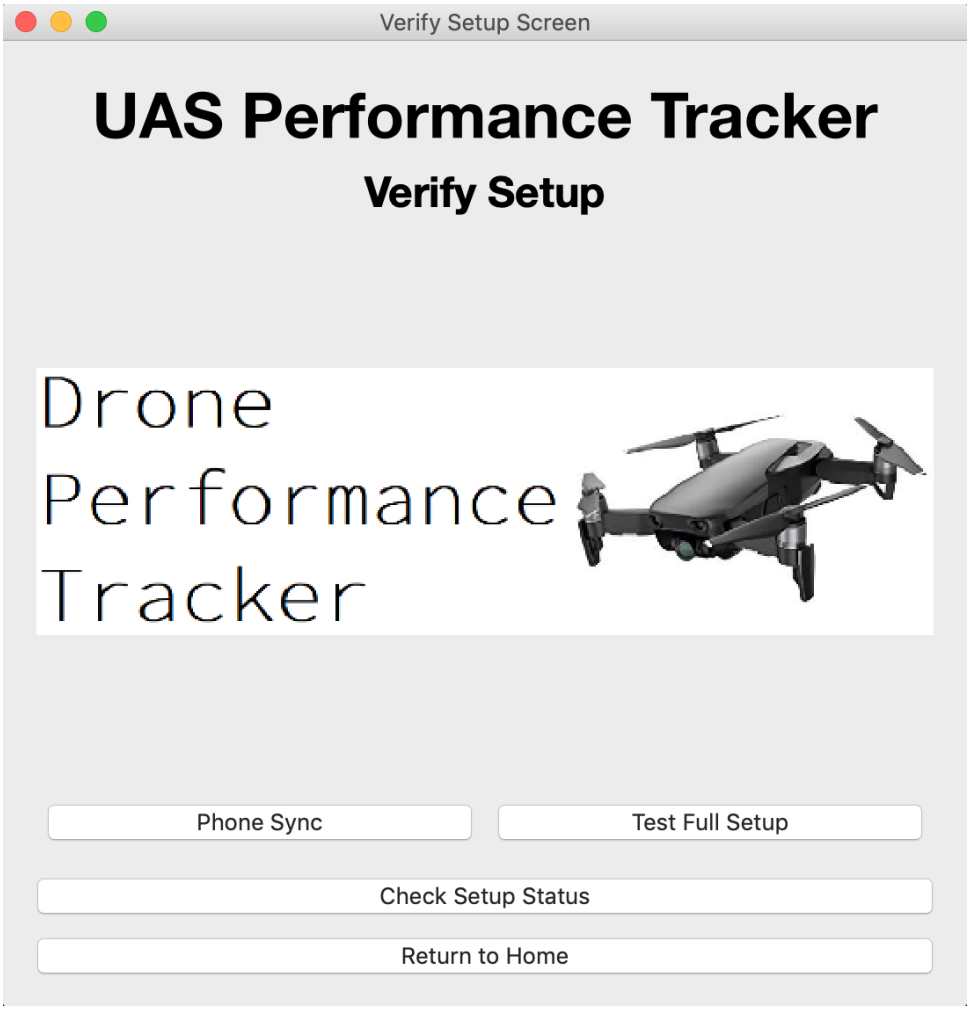

Figure 11: Set Up Screen

The user should first click the 'Phone Sync' button and then press the Connect button on the Phone App, once the information has been entered into the phones as explained in section 2.3. The user should wait for the system to pop up a message box, either displaying a successful phone connection or an error message. Next, the user should click the 'Test Full Setup' button. This runs a system-wide test to ensure everything is ready for tracking. Again, the user should wait for a pop up message displaying success or failure as shown in Figure 12.

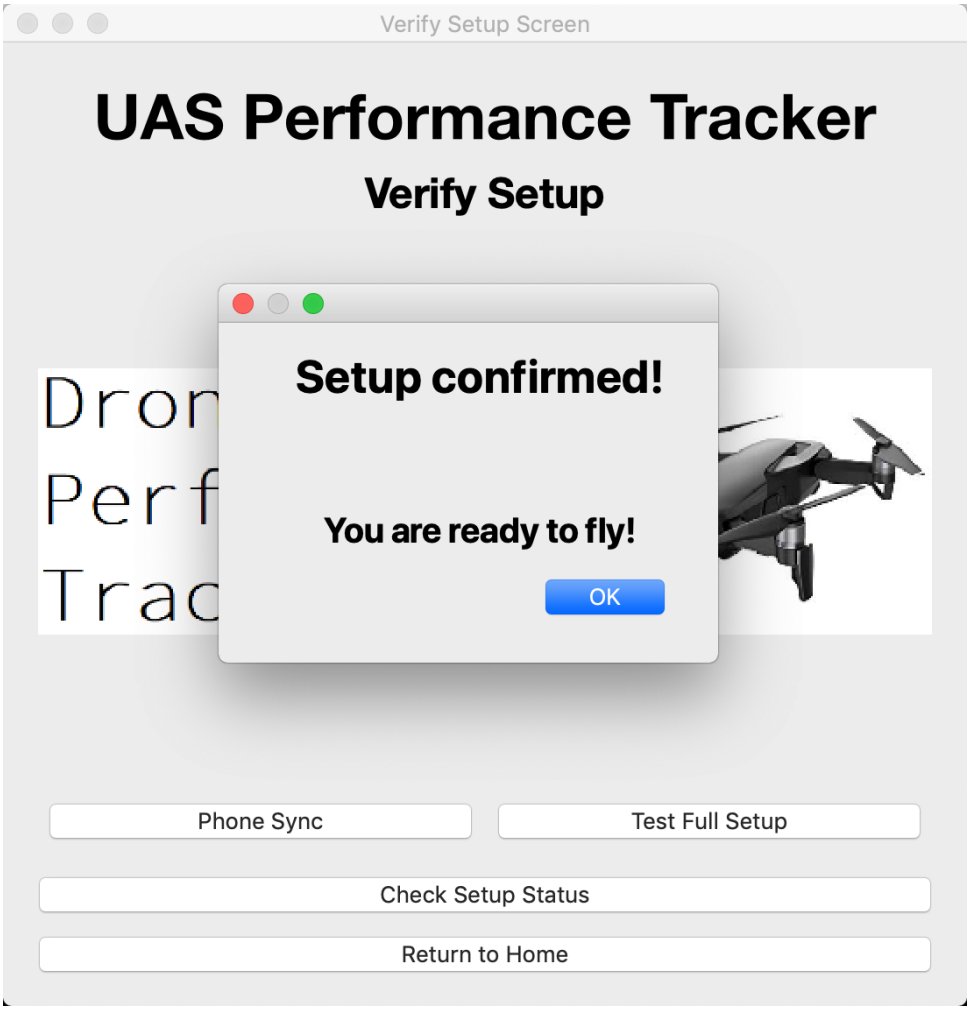

Figure 12: Set Up Success

In the case of failure, the user should go back to Section 2.0 of the User Manual to ensure that the hardware has been set up correctly.

Once the success message is displayed, the user should press the 'Return to Home' button to return to the Home Screen. The user should find that the 'Start Tracking' button is now enabled and no longer shown in red as seen in Figure 13. The user can push this button to transition to the Tracking Screen.

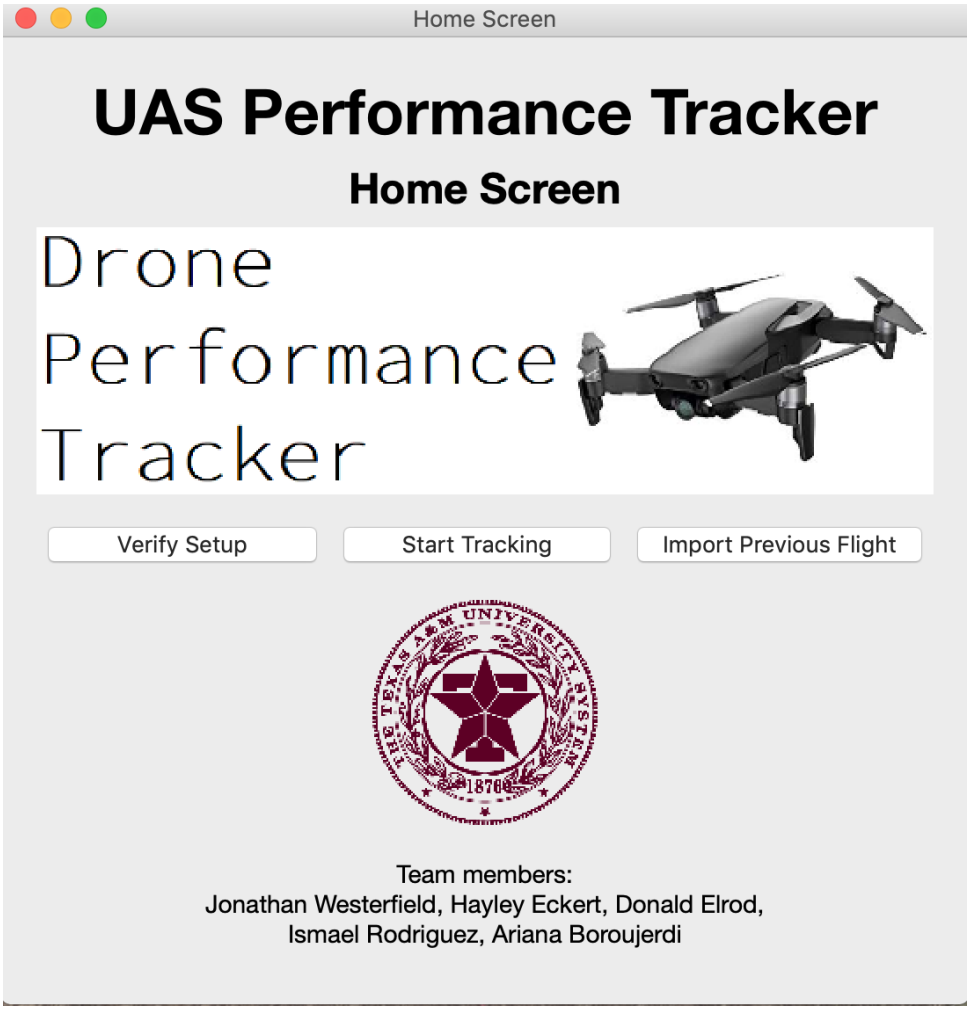

Figure 13: Home Screen with Tracking Enabled

3.3 Tracking Screen

Upon clicking the 'Start Tracking' button on the home screen, the user is taken to the Tracking Screen shown in Figure 14. On this screen, the user can enter in key flight information as well as control the starting and stopping of footage collection.

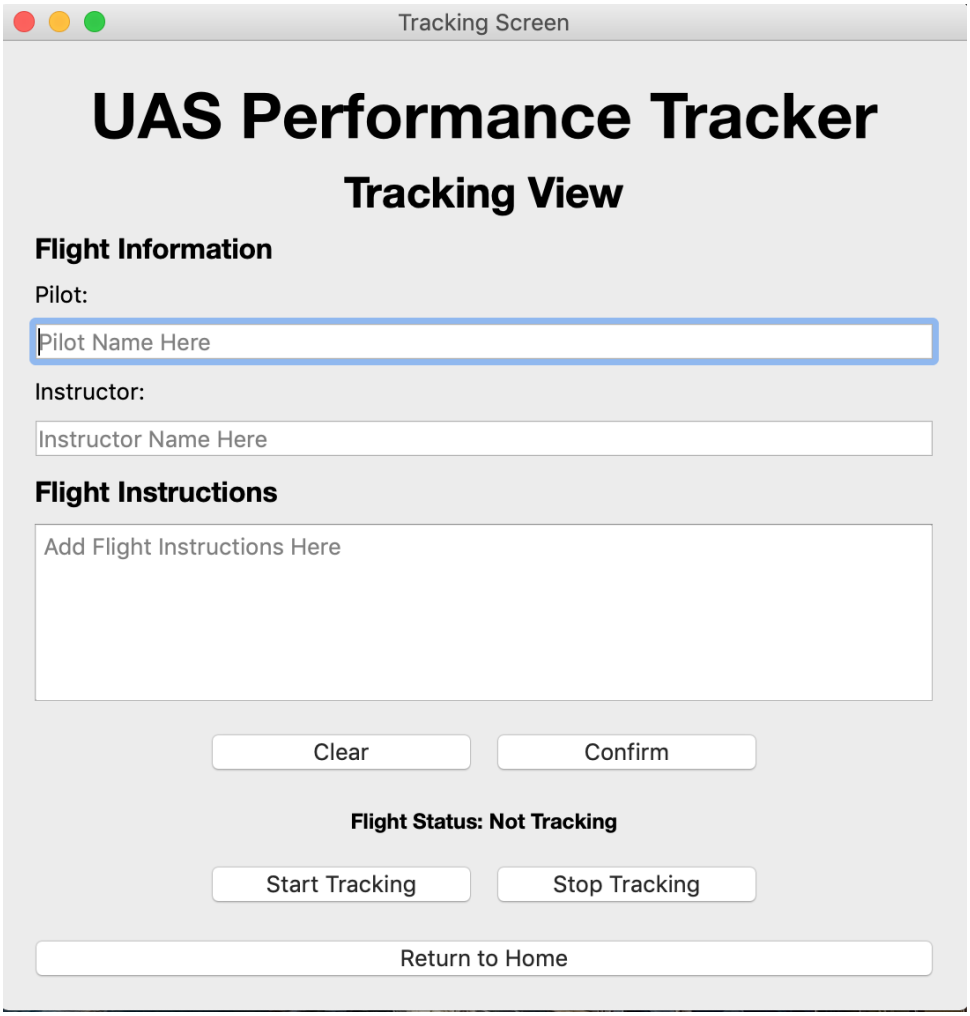

Figure 14: Tracking Screen

The user should first enter in the flight information into the text boxes then press the 'Confirm' button. The inputted information will be displayed in a pop up for visual confirmation as shown in Figure 15.

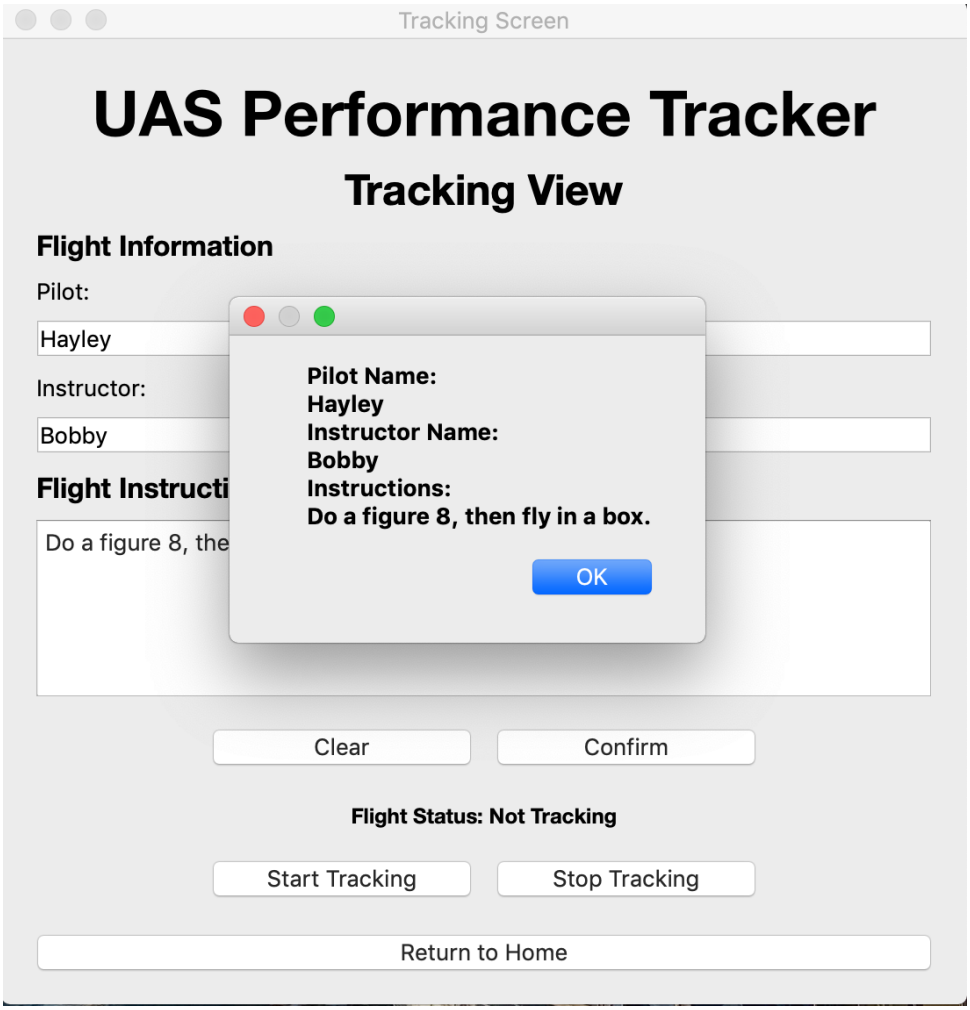

Figure 15: Tracking Screen with Confirmation

The user can then initiate tracking by clicking the 'Start Tracking' button. This sends a signal to the phones to begin recording video footage. A message box will pop up displaying that the tracking has been started. The user can then wait for up to 10 minutes before pressing the 'Stop Tracking' button to stop the collection of video footage. After pressing this button, a pop up message will again be displayed before the user is taken to the Loading Screen.

3.4 Loading Screen

The user will be automatically be taken to the loading screen after pressing the 'Stop Tracking' button on the Tracking Screen. This screen is shown in Figure 16.

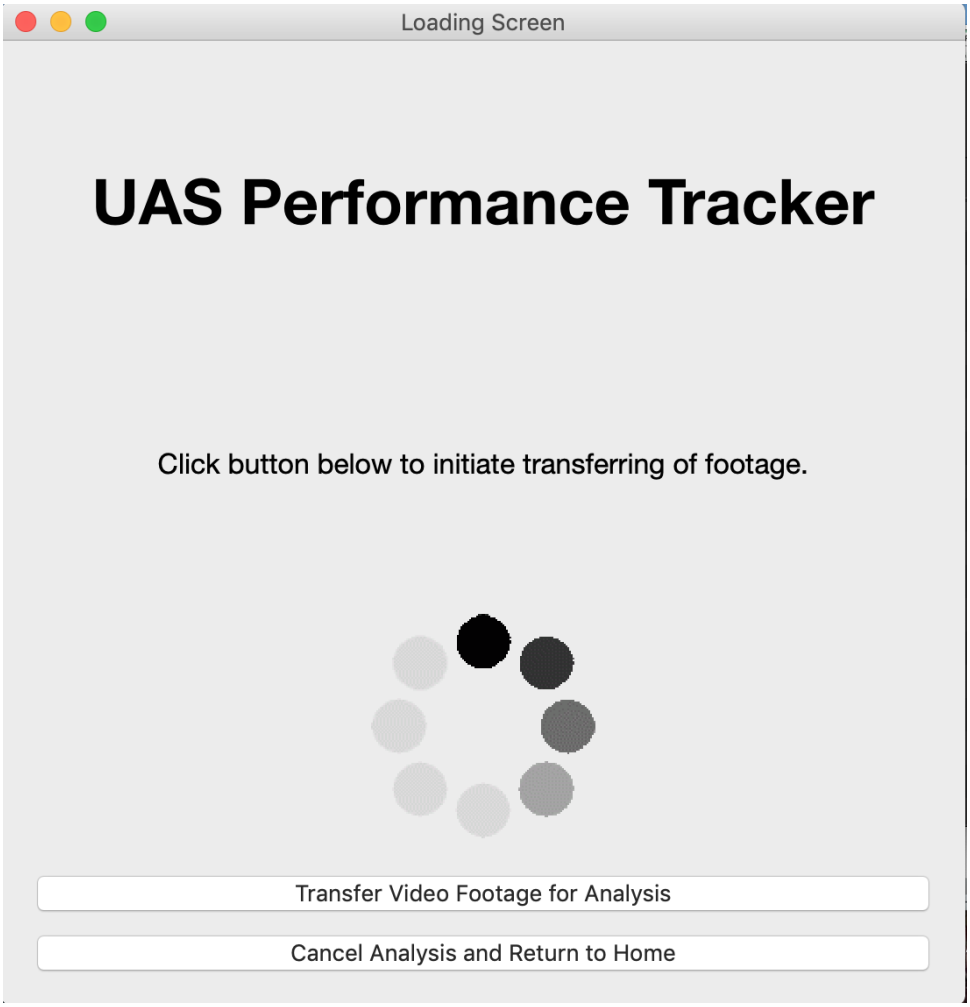

Figure 16: Loading Screen

Once on this screen, the user must press the 'Transfer Video Footage for Analysis' button to initiate the transfer of the video footage from the two phones to the computer. The user will see a pop up message displayed once the process has been initiated and must wait while the footage is transferred. The user should patiently wait during this time and not interfere with the program. This is shown in Figure 17.

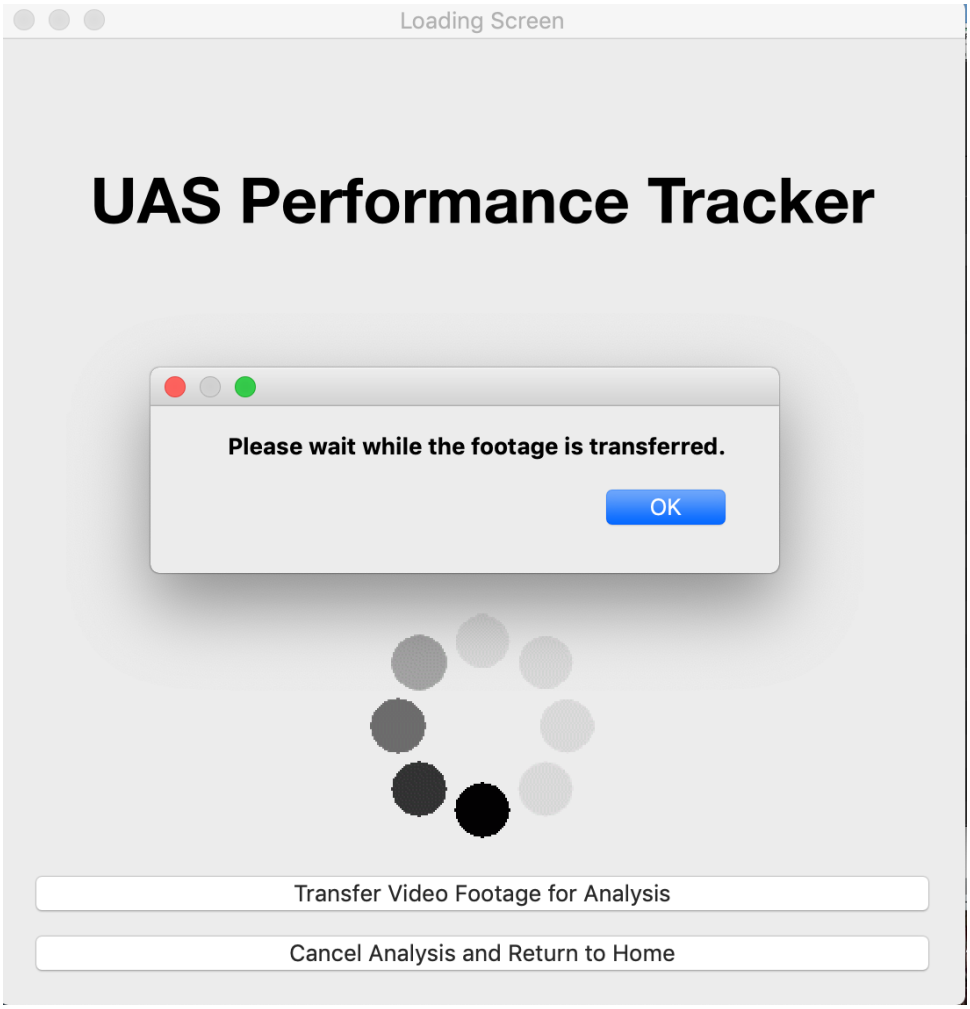

Figure 17: Loading Screen while Results are Transferred

When the footage transfer is complete, the user interface will automatically display the Image Detection screen, discussed in the next section.

3.5 Image Detection Screen

When the screen in Figure 18 is displayed to the user, the user must identify the drone in the collected video footage so that the computer vision software can track and compute coordinates for the drone for the duration of the footage.

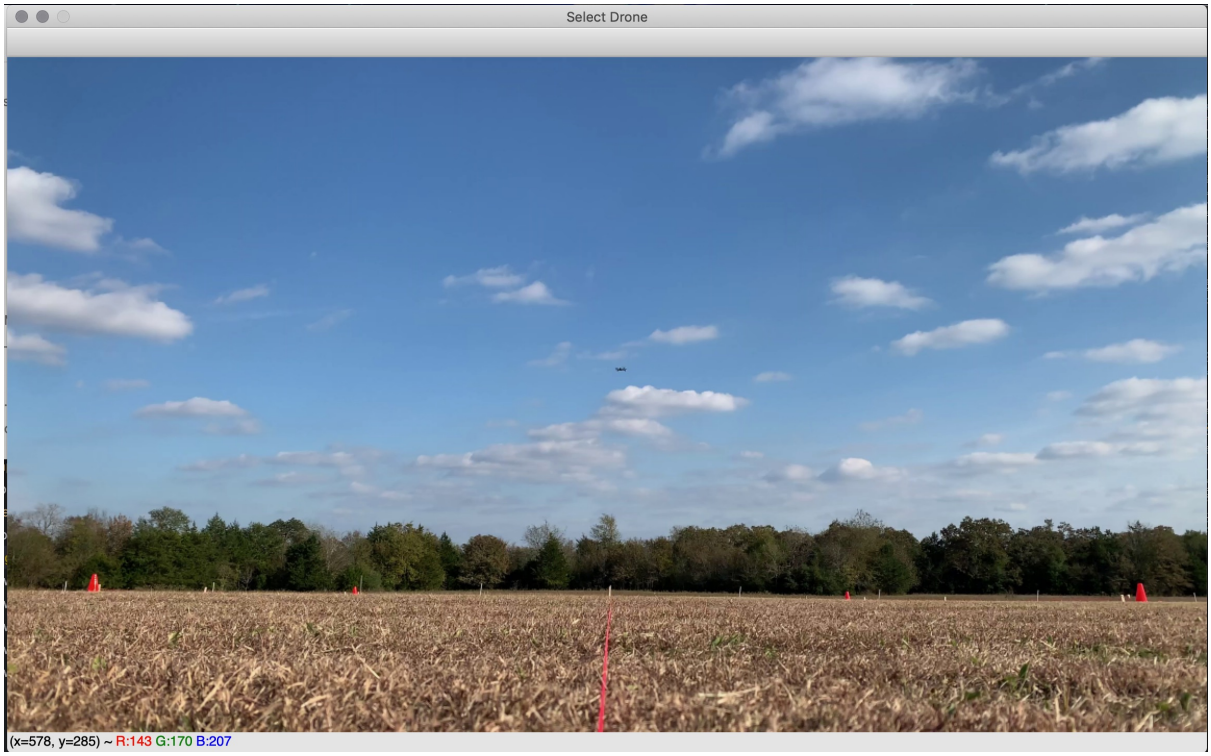

Figure 18: Drone Selection Window

First, the user must use the computer mouse or trackpad to draw a bounding box around the drone in the displayed image. This is displayed in Figure 19. Once the user is pleased with the bounding box, the keys 'space' and 'enter' will alert the system that the selection on screen is where the drone is located, and it will begin processing that video. As there are 2 videos and to avoid delays, both videos are tracked at once, so the user will have to select the drone from both views.

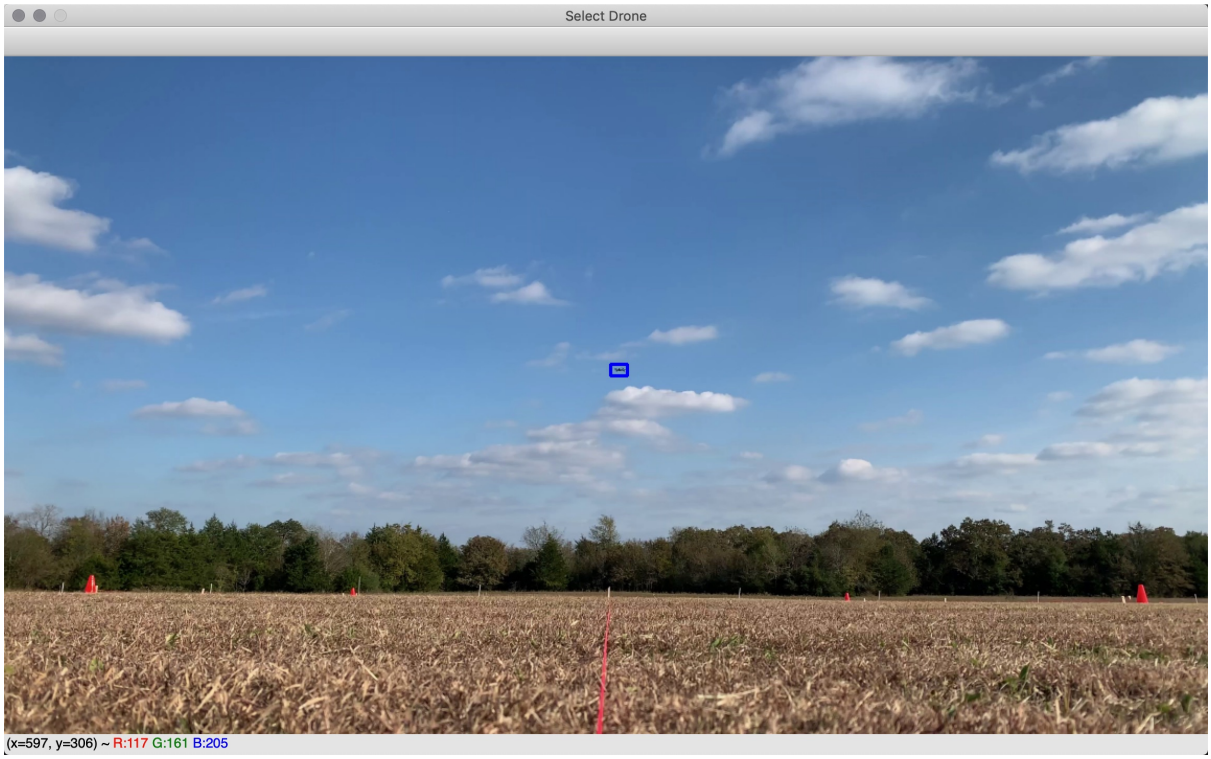

Figure 19: Drone Tracking window

If the tracker loses the drone, and knows that it lost the drone, it will pop up a very similar image to the initial drone selection image, however with a message at the top left saying that the tracking failed. At this point, the user can select the drone again and once again press 'space' or 'enter', but the user can also press 'escape' to skip frames of the video if the drone is out of frame. The frame skipping increases the more times you press 'escape', up to a maximum of 3 seconds per button press. Once the drone is back in frame, just draw the bounding box again and press 'enter' or 'space'.

If the tracker loses the drone due to background noise, such as a bird flying behind or in front of the drone or the drone flies in front of a dark background, the user can press 'r' and it will bring up the drone selection screen again, allowing the drone to be manually re-selected at any time during the tracking.

Once a video has been fully processed, the tracking window will close. Once both videos are finished, the program will transition immediately to the flight report screen.

Note: If the weather is poor or the lighting is bad, expect a lot of errors while tracking, as the drones are small in the footage and potentially easy to lose in bad conditions.

3.6 Flight Report Screen

After the software has completed the flight analysis, the user will be redirected to the Flight Report Screen as shown in Figure 20. On this screen, the user can view the results of the drone flight, both graphically and statistically.

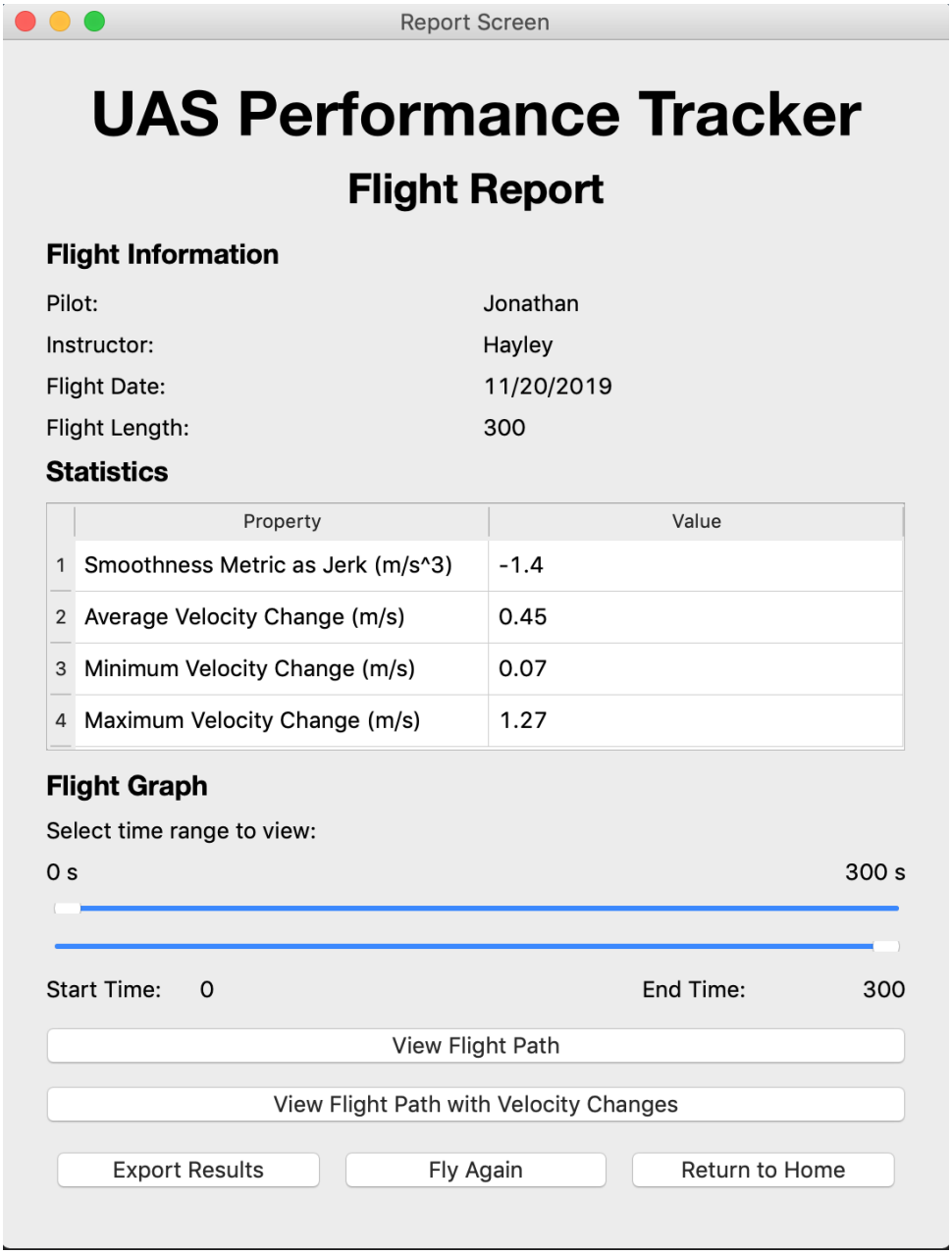

Figure 20: Report Screen

The first section of the report view contains the flight information, as entered on the Tracking Screen. This consists of the pilot name, instructor name, flight date, and flight length.

The next section contains computed flight statistics, namely, the smoothness score for the flight, the average change in velocity between consecutive points, the minimum change in velocity, and the maximum change in velocity.

The last section allows the user to view the flight path graphically. The user has two options for viewing the flight path: without velocity changes displayed or with velocity

changes displayed. For both options, the user can use the two sliders to limit the points that will be displayed on the graph within the time range. Note that the starting time must be earlier than the end time or an error message will be displayed as a pop up to the user.

To view the flight path as a series of data points, the user should press the 'View Flight Path' button. This generates a draggable 3D plot of the legal data points during the drone's flight as shown in Figure 21.

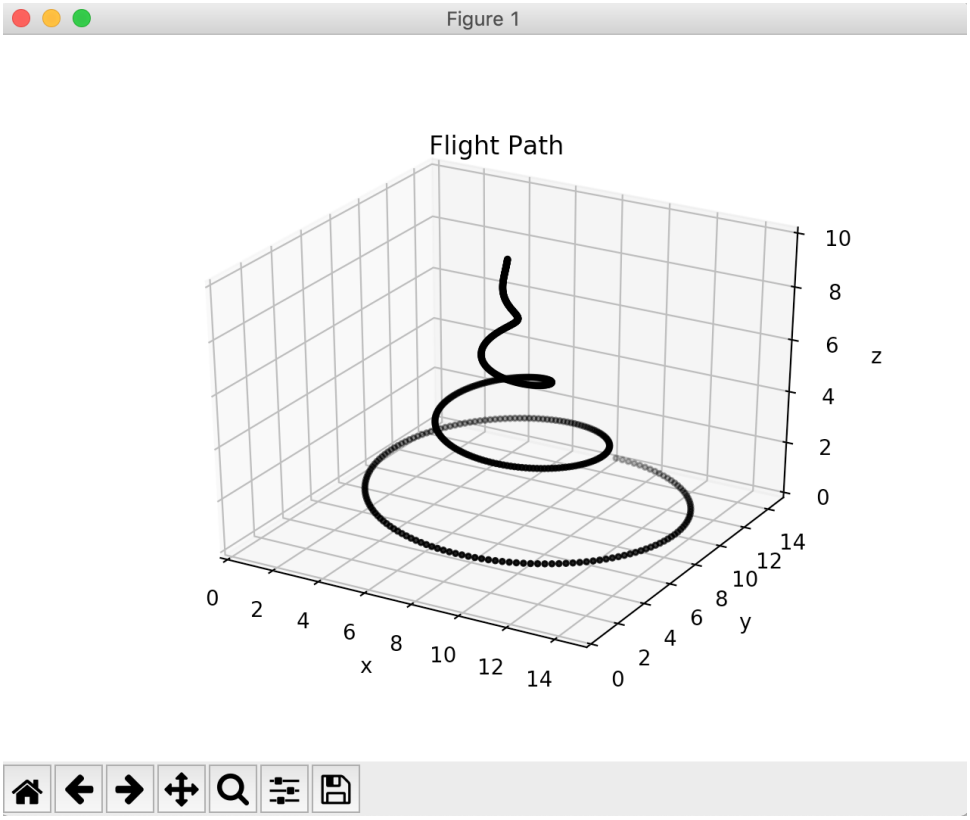

Figure 21: Flight Path Graph

To view the flight path as a series of data points with velocity changes displayed, the user should press the 'View Flight Path with Velocity' button. This again generates a draggable 3D plot, but the points on the graph are colored with regards to the velocity change from the previous point. Consecutive points are also connected with a colored line with regards to the velocity change from the first point of the line. A color of red represents a velocity change less than the total flight average velocity change, a color of green represents a velocity change greater than the total flight average velocity change, and a color of yellow represents a velocity change within 0.5 m/s of the total flight average velocity change.

The user can save the results for later viewing by pressing the 'Export Results' button in Figure 20. This saves the flight results in a "`.flight`" file in the Flights folder with the naming convention `PilotName_MM-DD-YY-HH-MM-SS.flight`. These "`.flight`"

files can be imported using the "Import Previous Flight" button on the Home Screen.

Throughout the user interface, any errors will be displayed visually to the user with pop-up boxes. For additional error handling information outside of the scope of the user manual, please consult the programmer's manual.

3.7 The Smoothness Metric of the Flight

The smoothness metric is derived from the Log Dimensionless Jerk formula. This was used because this is largely regarded as the most reliable smoothness metric used in medical studies involving the smoothness of motion in patients with neurodegenerative diseases. *The closer to 0 the output of this formula is, the smoother the flight is.* The function takes in array of velocities (ours were derived from the velocities between different points of the flight) and computes the jerk from those velocities. This means that the longer the flight is, the higher the jerk would be. The more velocities that are input into the LDLJ formula determine how smooth the flight and this is the reason that the jerk gets impacted. The longer the flight is, the worse the LDLJ will be, meaning that the only way to compare flight smoothness is to compare the Jerk between different flights with the same flight time. Log Dimensionless Jerk (LDLJ) is based off of Dimensionless Jerk (DLJ). The formulas for both are shown below.

$$DLJ = -\frac{(t_2 - t_1)}{v_{peak}^2} \int_{t_1}^{t_2} \left| \frac{d^2 v(t)}{dt^2} \right|^2 dt$$

$$LDLJ = -\ln |DLJ|$$

4 File Structure

This describes the file structure created by the application.

The system will automatically create a directory called `drone-tracker` that contains folders titled FTP, OpenCV, and Flights once run. These folders will be empty initially but will be populated automatically as the system runs. First, the FTP folder will be populated with the videos that are transferred from the phones after tracking a flight. This folder will only ever contain 2 videos (immediately after the video footage is transferred) and will automatically be cleared out once the flights have been analyzed. This way, the privacy of the drone pilot is respected. Second, the OpenCV folder contains the coordinates computed from the OpenCV analysis of the recorded videos. It will be used by the system and again does not require user interaction. Lastly, the Flights folder is where the flight reports will be saved if exported from the report view screen; thus, when importing a past flight, the user should choose a file from this directory. The template for naming the files will be exported in the following way: `PilotName_MM-DD-YY-HH-MM-SS.flight`. The ".flight" extension is a custom extension, based off of JSON. In every ".flight" file, the necessary information to repopulate the Report View of a flight is stored; however, the actual flight video footage is not saved.