Fly Sense

Team C – Test Plan

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1. Introduction

This document describes the test plan that Team C will follow for the FlySense project during the spring 2018 semester. It includes the schedule of tests, the specific details of each test, and information about how the tests will ensure that the system meets design requirements.

For the Spring Validation Experiment (SVE), the team will present a fully functional system consisting of a flying quadcopter with the FlySense suite fully deployed on board and controlled from land using the User System, which consists of Augmented Reality Headset, our communications solution and the quadcopter radio controller.

During the Fall semester we developed the aerial and user sub-systems with the bird's eye view and the heads-up display functionality, along with a voice commands-based user interface. To fast track the process of testing, we designed a push-cart system which was used to validate some of the system requirements.

This semester our biggest challenge is to ensure all those systems are well-integrated with the flight system and tested thoroughly in flight. We also expanded our requirements to include a safety feature, which we are calling the "STOP" feature. The goal of this feature is to prevent the system from hitting any obstacle.

To ensure that we develop a robust system which meets our design requirements, we have organized the tests based on architectural hierarchy. The tests range from component level tests (newer or revised components) to sub-system tests (either previously tested on the ground or with a new component added) and finally the full-functionality system tests.

2. Logistics

All testing activity at component and sub-system level will be handled by the team members. Testing personnel will change across tests as described in the relevant sections.

3. Schedule

The following tentative schedule will guide all our testing activity this semester, from component level, to sub-system to full system testing and SVE.

Test ID	Architecture	Test name	Date
T01	Sub-system	Quad Flights with Weights	2/10
T02	Component	Power Module Test	2/12
T03	Component	Communications Test	2/10
T04	Sub-system	Log flight data to tune flight dynamics	2/13
T05	Sub-system	Flight with Velodyne and Jetson onboard	2/20
T06	Component	Test FPV Camera	2/14
T07	Sub-system	Flight with Velodyne, Jetson and FPV camera	2/28
T08	Sub-system	Flight to Evaluate Birds Eye View, sound warnings	3/7
T09	Sub-system	Flight to evaluate "Stop" functionality	3/21
T10	Sub-system	Flight with new video feed merging FPV and user widgets	3/14
T11	System	SVE Dry run 1 (NREC)	4/4
T12	System	SVE Dry Run 2 (Nardo)	4/11
T13	System	SVE	4/25

4. Tests

T01: Quad Flights with Weights

Item	Description
Objective	• Check flight stability with maximum payload weight
Elements	• Flight hardware
Location	• Schenley Park
Equipment	• DJI Matrice 100 • DJI Matrice Remote Control Joysticks • Weights
Personnel	• Nick Crispie, Shivang Baveja
Procedure	1. Attach weights securely to quad 2. Weigh entire weighted quad, verify it is 3.6kg 3. Hover for 5 minutes at constant position and observe vertical oscillations 4. Fly back and forth in 30m straight lines. Start slow (1m/s) and progress faster (up to 5 m/s). Observe stability. 5. Record flight time and battery drain 6. Add additional weights above 3.6kg as deemed acceptable (target 200g)

	7. Repeat steps 3 through 6
Verification criteria	● Determine estimated flight time at given weight ● Determine maximum reasonable weight to fly the quad (within safety factor and expectation of full hardware system)

T02: Power Module Test

Item	Description
Objective	● Validate all flight hardware will be adequately powered
Elements	● Flight Hardware
Location	● MRSD Lab-NSH B506
Equipment	● Volt Meter ● DC voltage supply ● DJI Matrice 100 with battery
Personnel	● Nick Crispie
Procedure	1. Attach power module to DC power supply at 25V. Check power output (current and voltage) 2. Attach DC motor to power module, run for 10 minutes 3. Attach power module to DJI M100 power outlet, run motor for 10 minutes 4. With power module attached to DJI M100, attach Jetson power cable. Run Jetson 5. With power module attached to DJI M100, attach Jetson and Velodyne VLP16 power cables.
Verification criteria	● Power module must output be 12V +- .5V ● Power module must be sufficient to run small DC motor without overheating ● Power module must be sufficient to run both Jetson and Velodyne without issue

T03: Communications Test

Item	Description
Objective	● To test the Ubiquiti AC-M access point as a ground WiFi unit to which the aerial system and the user system will be connected
Elements	● Range on 5Ghz ● Range on 2.4Ghz-interference with DJI ● Range with Omni-directional stock antennas ● Range with high gain directional patch antenna
Location	● Schenley Park

<table>
<tr><td>Equipment</td><td>Jetson TX-2 mounted on quad-copter (only to get power from the quadcopter power-rail), Ubiquiti AC-M access point with 2 sets of antennas (powered via external battery), Laptop</td></tr>
<tr><td>Personnel</td><td>Shivang, Nick, Nihar</td></tr>
<tr><td>Procedure</td><td>Setup:
Move to an open, flat area in Schenley Park
Ensure omni-directional antennas connected to the Wi-Fi access point.
Power up all the systems
Ensure laptop, Jetson and Epson are all connected to the access point.
Broadcast video and telemetry data from Jetson, check that we can receive on Epson and Laptop
Test1: Benchmark with omni-directional antennas
1 person will pick up quadcopter & move away from the Wi-Fi access point.
Observe data stream at laptop and Epson.
The person with the quadcopter will keep walking away until connection is lost or 100m is reached.
Return when any of the two conditions are met
Testers on the ground station will record the range and quality degradation seen with increasing distance.
Test2:
Switch to directional antennas
Ensure that all the units are connected to the access point.
1 person will pick up quadcopter & move away from the Wi-Fi access point.
Observe data stream at laptop and Epson.
The person with the quadcopter will keep walking away until connection is lost or 100m is reached.
Return when any of the two conditions are met
Testers on the ground station will record the range and quality degradation seen with increasing distance.
Power off all systems</td></tr>
<tr><td>Success Criteria</td><td>Range should be greater than 30m when using omni directional antennas.
Range should be greater than 60m when using Directional antenna.</td></tr>
</table>

	● Data stream at Laptop should be robust and without lag till 60m ● Data stream at Epson should be robust and without lag till 60m

T04: Log flight data to tune flight dynamics

Item	Description
Objective	● Gather odometry and pilot inputs on different flight modes in order to understand the impact of quad parameters on its dynamics (mass/weight, drag, speed cut-off limit)
Elements	● Sensors, Flight unit
Location	● Schenley Park
Equipment	● DJI M100 Flight system ● Velodyne VLP 16 Lidar ● Nvidia Jetson TX2
Personnel	● Nick, Shivang, Joao
Procedure (Test A: Straight line)	● Set maximum cut-off speed to 2 m/s ● Fly the quad to at least a 5-meter altitude for safety ● Fly quadcopter full throttle forward ● Wait for quadcopter speed to stabilize at max cut-off ● Stop all inputs and let the quadcopter stop by itself ● Repeat several times gradually increasing cut-off speed
Procedure (Test B: Curved line)	● Set cut-off speed to 2 m/s ● Fly the quad to at least a 5-meter altitude for safety ● Fly the quadcopter until it reaches the max cut-off speed ● Introduce maximum input possible to the right ● Keep input constant until the quadcopter performs a curve ● Repeat procedure to the left side ● Stop all inputs and let the quadcopter stop by itself ● Repeat several times gradually increasing cut-off speed
Verification criteria	● Odometry logged successfully with correct time stamping ● Pilot inputs logged successfully with correct time stamping

T05: Flight with Velodyne and Jetson

Item	Description
Objective	● Check stability of aircraft with full system onboard ● To collect data from Velodyne and DJI quadcopter in flight. ● To test communication to the quad over 5Ghz wifi.
Elements	● Sensors, flight system and communication
Location	● Schenley Park/CMU
Equipment	● DJI M100 Flight System, DJI Flight controller, iPhone

	● Velodyne VLP16 ● Jetson TX-2 ● Ubiquiti AC-M WiFi access point ● Laptop
Personnel	● Shivang, Nick, Hari
Procedure	Flight 1: ● Takeoff, hover for 3 min and land. ● Conduct physical checks to ensure all onboard systems are still fine. Flight 2: System stability, communication test ● Takeoff, climb to 5m, roll, pitch and yaw to check lateral and longitudinal stability, land. ● Check live stream of data on laptop ● Let system hover until battery reaches 30% mark, then land. ● Download and check the recorded data Flight3: Point cloud and flight data collection test ● Takeoff, climb to 5m, hover for 1 min, move in an area of 20m x 20m ● Move near tree, wall maintaining at-least 5m from them. ● Climb to 10m, move the quad in the same area ● Land
Verification criteria	Flight related: ● Stable flight with Velodyne, Jetson onboard ● Velodyne and Jetson fully functional after landing Functionality related: ● Point cloud data and Quadcopter flight data logged ● reliable and continuous communication all throughout the flights

T06: Test FPV Camera

Item	Description
Objective	● Check video streaming quality of the on-board camera
Elements	● Camera stream ● Display video stream on Epson BT 300 ● Processing on the Jetson TX2
Location	● Schenley Park/CMU

Equipment	• Epson BT 300 • Jetson TX2 • ELP USB camera
Personnel	• Nihar, Hari
Procedure	• Connect the ELP USB camera to the Jetson TX2 and power up the device • Start the ROS nodes to stream data on a topic • Setup the Epson augmented reality headset and open the FlySense application • Home screen will display the FPV video stream
Verification criteria	• ROS nodes connect without major issues • Video stream is discernible • Video stream is smooth without lag

T07: Flight with Velodyne, Jetson and FPV camera

Item	Description
Objective	• Check stability of aircraft with full system onboard • To collect data from Velodyne Lidar • To test communication to the quad over 5Ghz Wi-Fi.
Elements	• Velodyne 3D point cloud stream • Camera stream • Wireless Connectivity • Quadcopter Flight • Ground station monitoring
Location	• Schenley Park/CMU
Equipment	• Jetson TX2 • ELP USB camera • DJI Matrice 100 • Velodyne Puck
Personnel	• Nihar, Shivang, Nick
Procedure	• Setup the quad in the flying zone • Secure perimeter • Fly the quad in auto take off mode • See for instability, altitude variation and drifts • Check for wireless connectivity between the quad & computer • Check Velodyne Lidar stream/logs • Check video stream on computer • Land quad in auto landing mode
Verification	• Quad takes off without any glitches

criteria	● No major instability while stationary in air ● Wireless connection is seamless ● Lidar stream is as expected ● Video streaming is smooth ● Quad lands without any glitches

T08: Flight to Evaluate Birds Eye View, sound warnings

Item	Description
Objective	● To evaluate the color coding algorithm for the point clouds ● To understand the reception and display rate of the point clouds on the AR interface ● To evaluate the algorithm for sound warnings in 3D and also understand the user experience
Elements	● AR interface, Sensors, Communication system, Backend algorithms
Location	● Schenley Park/NREC
Equipment	● DJI M100 Flight System, DJI Flight controller, iPhone ● Velodyne VLP16 ● Jetson TX-2 ● Ubiquiti AC-M WiFi access point ● Laptop ● Epson BT-300, earphones
Personnel	● Full team
Procedure	Flight 1: Trial flight to check data reception ● Take off, climb to 5m altitude & move within an area of 10m x 10m ● Check reception of colored point clouds on AR interface Flight 2: Check Birds Eye View in pre-determined environment ● Take off and climb to 5m altitude ● Fly pass by tree (note: clearance will be artificially big so that the system identifies it as a collision) ● Check the transition of color in the point cloud of this tree alone in the AR interface ● Print expected time to impact in the terminal of the ground system computer and note the transitions based on the pilot's observation Flight 3: Check sound warnings in pre-determined environment ● Take off and climb to 5m altitude ● Move between rows of trees (appearing both left and right at least twice) at 2m/s maintaining 5m clearance

	● Print time to impact, frequency of beeps and the location (L/R) on the terminal of the ground system computer ● Listen to the audio warnings on the Android phone and the AR interface ● Fly to open space after the last tree and hover ● Land
Verification criteria	● Data reception is real time with minimum latency ● Color of the point clouds representing the target change from green to red to yellow based on the limits we estimated ● Sound warnings appear in the correct ear (multiple times in both left and right sides) ● Sound warnings become more prominent as vehicle flies closer and fades as it moves away

T09: Flight to evaluate "Stop" functionality

Item	Description
Objective	● Evaluate if the stop functionality correctly blocks inputs that would make the quad "crash in a virtual wall"
Elements	● Sensors, Flight unit, "Stop" functionality
Location	● Schenley Park
Equipment	● Quadcopter, Velodyne, Jetson
Personnel	● Nick, Shivang, Joao
Procedure	● Set the quad maximum cut-off speed to 2 m/s ● Fly the quad to at least a 5-meter altitude for safety ● Introduce a virtual wall in the LIDAR data ● Move the quadcopter away from the virtual wall ● Ensure enough clearance so that the quad can reach maximum cut off speed ● Fly the quad copter directly to the wall at 90^0 angle ● Repeat procedure with different approach angle ● Repeat procedure gradually increasing cut-off speed
Verification criteria	● Movements towards the wall are gradually constrained ● All movements away from the wall were not constrained ● Process is smooth with minimum jerks ● Process is independent of speed (provided there is an actual solution for the starting conditions)

T10: Flight with new video feed merging FVP and widgets

Item	Description
Objective	● Test if the new video feed merging the FVP and widgets in a single screen can be rendered onboard the quadcopter real time
Elements	● Sensors, Flight unit, AR unit, Communications
Location	● Schenley Park
Equipment	● Quadcopter, Velodyne, Jetson, Camera, Radio
Personnel	● Nihar, Nick, Shivang
Procedure	● Set the quad maximum speed to 2 m/s ● Fly the quad to at least a 5-meter altitude for safety ● Turn on the FVP view feed in the Epson ● Fly the quadcopter for several minutes at around 10 meters distance from the pilot ● Gradually increase the range & monitor the image quality ● Repeat the procedure gradually increasing cut-off speed
Verification criteria	● Measure delay/latency and image degradation ● Image can be rendered with quality onboard ● Image can be received with quality on land ● Image can be presented with quality on the Epson

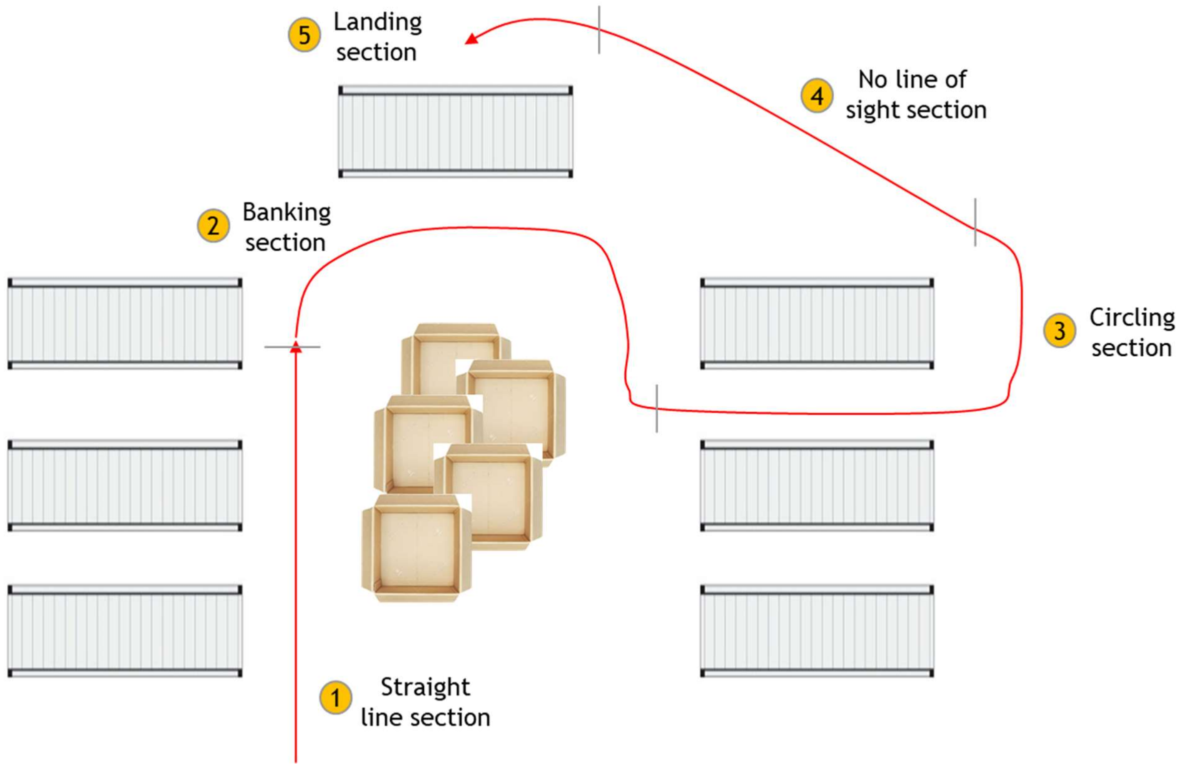
T11: SVE Dry run 1 (NREC)

Item	Description
Objective	● Test all the subsystems together as one unit in mission environment ● Understand the user experience for every mode, and the complete interface ● Gather internal feedback about the user system, and understand the scope for improvement
Elements	● Complete system
Location	● NREC
Equipment	● DJI M100 Flight System, DJI Flight controller, iPhone ● Velodyne VLP16 ● Jetson TX-2 ● Ubiquiti AC-M WiFi access point ● Laptop ● Epson BT-300, earphones
Personnel	● Full team
Procedure	Test 1

	● Set up an environment with few obstacles and opportunity to navigate just like a maze ● Predefine a path that involves moving up to 5m of one obstacle, and maneuvering around it ● Extend the path to contain 3 more obstacles to the goal ● Take off and climb to 5m altitude ● Fly quadcopter along the predefined path using FPV and Bird's Eye View ● Hover and land after reaching the goal ● Gather feedback from pilot to check for improvements
Verification criteria	● Data reception on the AR interface is real time ● Birds Eye View images are clear, and obstacles are distinguishable ● Point clouds show the expected transition of colors ● Sound warnings appear only when needed and are not intrusive to some extent ● Pilot safely guides the vehicle to the goal and lands

T12: SVE Dry Run 2 (Nardo)

Figure1:



Item	Description
Objective	● Test all the subsystems together as one unit in SVE test environment ● Understand the pilot experience for every mode, and the complete interface ● Gather all the necessary feedback to improve the system before SVE
Elements	● Complete system
Location	● Nardo Airport
Equipment	● DJI M100 Flight System, DJI Flight controller, iPhone ● Velodyne VLP16 ● Jetson TX-2 ● Ubiquiti AC-M Wi-Fi access point ● Laptop ● Epson BT-300, earphones
Personnel	● Full team ● David Murphy (NEA)
Procedure	Test 1 1. Set up Environment according to Figure 1 2. Fly quadcopter along the predetermined route without the Bird's eye view aid or sound warnings (only FPV). 3. Fly quadcopter along the same route with the Bird's eye view and sound warnings 4. Fly 2nd time without sound warnings 5. Gather feedback from pilot about the scope for improvements in the system and the test Test 2 1. Fly in an open field towards virtual obstacle at constant speed (~3 m/s) 2. Give consistent control even as quadcopter comes to complete stop 3. Fly quadcopter parallel to the virtual obstacle 4. Gather feedback from pilot about the scope for improvements in the system and the test
Verification criteria	● Pilot completes assisted trial in less time and fewer close encounters with obstacles. ● Point clouds are colored correctly, and pilot is able to infer the required information easily ● Sounds warnings convey current information without irritating the pilot

	● The controller Overrides pilot commands within 1 m of obstacle contact ● Pilot gives positive feedback about the assistive tech with very few suggestions to improve upon

T13: SVE

Item	Description
Objective	● Verify System Level Requirements ● Demo full system to Project stakeholders
Elements	● Full System Test
Location	● Nardo Airport
Equipment	● DJI Matrice 100 with FlySense Hardware ● Epson BT300 AR Headset ● Various cardboard obstacles
Personnel	● Full team ● David Murphy (NEA Pilot)
Procedure	Test 1 1. Set up Environment according to Figure 1 2. Pilot will fly quadcopter along route without the Bird's eye view aid or sound warnings (only FPV). 3. Pilot will fly quadcopter along specified route with the Bird's eye view and sound warnings 4. Pilot will fly 2nd time without sound warnings Test 2 5. Pilot flies in an open field towards virtual obstacle at constant speed (~3 m/s) 6. Pilot gives consistent control as quadcopter comes to complete stop 7. Pilot manually flies quadcopter parallel to the virtual obstacle
Verification criteria	● Pilot completes assisted trial in less time and fewer close encounters with obstacles. ● Bird's eye view is properly segmented with green, yellow, and red ● Sounds warnings convey current information within .2 seconds ● Detects all obstacles of size 2m x 2m or larger at 10m distance ● Overrides pilot commands within 1 m of obstacle contact