TEST PLAN

Team Kingfisher (J)

Eitan Babcock, Ryan Gibbs, Shu-Kai Lin, Kelsey Ritter, Samuel Wang

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1. Introduction and Definitions

The following document provides a detailed test plan for Project Kingfisher. It contains all details required to test each system and subsystem that will be completed, culminating in the Spring Validation Experiment in April, 2016. The tests were broken out into four large system-level tests, and nine smaller sub-system tests. A schedule is also provided detailing when the tests will take place, as well as the requirements and milestones associated with each test.

The following table provides definitions of terms used in the document.

Term	Definition
Mock ship deck	4’ x 4’ painted deck constructed from plywood on a 2x6 frame
Beacons	Infrared beacons with power supply
Quad/quadrotor	DJI Phantom II flying aerial vehicle containing all custom hardware systems such as computers, sensors, and mounting systems
NSH	Newell-Simon Hall on Carnegie Mellon University’s campus

2. Schedule

Due Date	Progress Review	Capability Milestone	Test Name	Associated Requirements
2/4/2016	PR 08	Localization Subsystem updated with Fisheye	Fisheye Calibration	Identify Deck
2/5/2016	PR 08	Localization works with quad motions	Coordinate Transform	Position of Deck Relative to Quad
2/5/2016	PR 08	Stability for hovering and decoupling of deck motion	Height Sensor	Predict Movement of Deck
2/8/2016	PR 08	Hovering	Hover Test	Safety
2/9/2016	PR 08	Hovering & Static Landing	Landing Test (static)	Land near center of deck
2/18/2016	PR 09	Ability to run without cables	Power Board	EMCON Conditions
2/18/2016	PR 09	Lighting invariant	Blinking	Operate in varying lighting conditions
2/20/2016	PR 09	Stability while deck moving	Optical Flow	Dynamic Moving Deck
2/23/2016	PR 09	State estimation with moving deck	State Estimator	Dynamic Moving Deck
3/10/2016	PR 10	Can predict safe landing points in future	Prediction	Predict Deck Dynamics
3/14/2016	PR 10	All subsystems fully mounted to platform	Assembly /Layout	Minimal User Input
3/24/2016	PR 11	Dynamic Landing	Landing Test (dynamic)	Land on dynamic deck
4/7/2016	PR 12	Dynamic Landing	SVE Rehearsal	Land near center of dynamic deck
4/20/2016	SVE	Dynamic Landing	SVE	Repeatability
4/27/2016	SVE Encore	Dynamic Landing	SVE	Robustness

3. System Tests

3.1. Hovering Test

Objective

The objective of this test is to demonstrate successful autonomous hovering relative to the deck.

Elements to be Tested

- Quadrotor
- Localization Subsystem
  - Fisheye camera
  - Beacon strobing
- IMU
- Trajectory Subsystem
- Trajectory generation
- Flight control Subsystem
- PID Position controller
- Flight control interface

Location

B-level of NSH

Equipment

- Mock ship deck
- Beacons
- Quadrotor

Personnel

Eitan Babcock, Ryan Gibbs, Shu-Kai Lin, Kelsey Ritter, Samuel Wang

Procedure and Verification Criteria

1. Place the deck at the dark corner of NSH B floor
2. Turn on the function generator to blink the beacons
3. Turn on the quadrotor and sensor suite
4. Launch all the software nodes in ROS
5. Manually take-off the quadrotor
6. Manually control the quadrotor to face the deck
7. Flip the switch of the transmitter of the quadrotor to enter autonomous mode
8. Observe the quad hovering
   a. The quad shall hover autonomously for at least 20s
   b. The quad shall drift no more than 15cm from its target location
   c. The quad shall not have a jerky motion
9. Flip the switch back to manual mode
10. Manually land the quadrotor and turn it off.

3.2. Landing Test (Stationary Deck)

Objective

The objective of this test is to perform a successful landing on a stationary deck.

Elements to be Tested

- Camera and image capture
- Image processing
- Localization
- Robot state estimator
- Flight control

Location

B-level of NSH

Equipment

- Mock ship deck
- Beacons
- Quadrotor

Personnel

Eitan Babcock, Ryan Gibbs, Shu-Kai Lin, Kelsey Ritter, Samuel Wang

Procedure

1. Power on the beacons on the deck
2. Power on the quadrotor, including all onboard components and sensors
3. Manually fly the quadrotor such that the beacons are in the camera's field of view
4. Switch to autonomous landing mode

Verification Criteria

The test is considered to pass if the robot safely and expediently lands near the center of the deck. The following metrics will be used as success criteria:

- Robot lands within 3 minutes of switching to autonomous mode
- Robot lands without damage to the robot, deck, or any surroundings
- Robot lands within 50cm of the center of the deck

3.3. Landing Test (Dynamic Deck)

Objective

The objective of this test is to perform a successful landing on a dynamic deck.

Elements to be Tested

- Camera and image capture
- Image processing
- Localization
- Quad state estimator
- Flight control
- Deck state estimator
- Prediction

Location

Sponsor’s warehouse space

Equipment

- Mock ship deck
- Actuation system for ship deck (provided by sponsor)
- Beacons
- Quadrotor

Personnel

Eitan Babcock, Ryan Gibbs, Shu-Kai Lin, Kelsey Ritter, Samuel Wang, sponsor representative

Procedure

1. Power on the beacons on the deck
2. Power on the actuation system for the deck
3. Power on the quadrotor, including all onboard components and sensors
4. Manually fly the robot such that the beacons are in the camera’s field of view
5. Switch to autonomous landing mode

Verification Criteria

The test is considered to pass if the robot safely and expediently lands near the center of the deck. The following metrics will be used as success criteria:

- Robot lands within 5 minutes of switching to autonomous mode
- Robot lands without damage to the robot, deck, or any surroundings
- Robot lands within 50cm of the center of the deck

3.4. Spring Validation Experiment

Objective

- Demonstrate stable hovering
- Demonstrate autonomous landing on a stationary deck
- Demonstrate deck motion prediction
- Demonstrate autonomous landing on dynamically moving deck

Elements to be Tested

- Integrated System

Location

Sponsor's warehouse space

Equipment

- Mock ship deck
- Beacons
- Quadrotor

Personnel

Eitan Babcock, Ryan Gibbs, Shu-Kai Lin, Kelsey Ritter, Samuel Wang, sponsor representative

Procedure and Verification Criteria

Demonstrate stable hovering

1. Turn on the beacons
2. Turn on the quadrotor and sensor suite
3. Launch all the software nodes in ROS
4. Manually take-off the quadrotor
5. Manually control the quadrotor to face the deck
6. Flip the switch of the transmitter of the quadrotor to enter autonomous mode
7. Observe the hovering motion of the quadrotor
    a. The quadrotor shall hover within ___ cm range in three dimension
    b. The quadrotor shall hover for __ secs
    c. The quadrotor shall not have any jerky movement
8. Flip the switch back to manual mode
9. Manually land the quadrotor and turn it off.

Demonstrate autonomous landing on a stationary deck

1. Power on the beacons on the deck
2. Power on the quad and all on-board components
3. Manually fly the robot so that the beacons are within the camera's field of view
4. Switch to autonomous landing mode
5. Allow autonomous mode to control quad

6. Upon the occurrence of one of the following conditions, manual control will be taken back: quad lands on deck, quad performs undesirable maneuver, or three minutes in autonomous mode has passed.
7. Power off the quad and the deck beacons.
8. If quad landed on deck, verify that all parts are intact and measure the distance from the center of the deck.

Demonstrate autonomous landing on dynamically moving deck

1. Power on the beacons on the deck
2. Power on the actuated deck.
3. Repeat steps 2-6 of stationary deck test.
4. Power off the actuated deck.
5. Power off the quad and the deck beacons.
6. If quad landed on deck, verify that all parts are intact and measure the distance from the center of the deck.

4. Subsystem Tests

4.1. Fisheye Lens Test

Objective

Demonstrate successful calibration of fisheye camera by ability to:

- Demonstrate accurate image rectification
- Demonstrate accurate computation of intrinsics matrix
- Demonstrate successful pose estimate with fisheye lens

Location

- Well-lit section of MRSD lab
- The dark corner of NSH B floor

Elements to be Tested

- Localization Subsystem
- Fisheye camera
- Strobed IR Beacons

Equipment

- PointGrey Chameleon 3 camera with fisheye lens
- Mock ship deck
- Beacons
- ROSbag software to record data
- Laptop running localization software package
- Planar calibration checkerboard

Personnel

Ryan Gibbs, Kelsey Ritter

Procedure and Verification Criteria

	Procedure Step	**Verification Metric**
1	Turn on the sensor suite	
2	Launch the localization subsystems in ROS	
3	Place planar calibration checkerboard close enough to camera to fill most of the rectified field of view	Fills 80% of rectified FOV
4	Visually inspect that the curvature of checkerboard shown in raw image becomes straight lines in the rectified image	Lines on checkerboard appear straight by inspection
5	Measure distance between plane of checkerboard to camera along camera axis	Measuring tape will be used to verify readings.
6	Measure size of the checkerboard in field of view	Measuring tape will be used to verify readings.

7	Calculate focal length by distance to plane and field of view.	
8	Verify calculated focal length	within 5% of value from calibration
9	Check the raw readings from camera lens to the center of the deck	The reading error shall not exceed 10%. Measuring tape will be used to verify readings.
10	Adjust the angle from the camera so that the deck is still in view but not centered	
11	Check raw readings from camera to center of lens again	The reading error shall not exceed 10%. Measuring tape will be used to verify the readings.
12	Repeat steps 10 and 11 for several representative angles	

4.2. Coordinate Frame Transform Test

Objective

- Demonstrate accurate coordinate transformation
- Prove the capability of accurate sensor feedback

Location

Dark corner of NSH B-level

Elements to be Tested

- Transformation Subsystem
- Transformation nodes

Equipment

- Deck
- Beacons
- ROSbag software to record data
- Laptop
- Previous fix 30-degree pitch sensor mount

Personnel

Eitan Babcock, Samuel Wang

Procedure and Verification Criteria

	Procedure Step	**Verification Metric**
1	Place the deck in the dark corner of NSH B-level	
2	Power on the beacons	
3	Power on the sensor suite	
4	Launch the localization subsystem in ROS	
5	Launch the transformation subsystem in ROS	
6	Manually hold the quadrotor with the beacons in view of the camera	
7	Check the raw readings from the camera to the deck	The error shall not exceed 10%
8	Check the transformed reading between the quadrotor and the deck	The error shall not exceed 10%
9	Manually pitch the quadrotor without losing sight of the beacons or translating the quadrotor	The reading shall not change from the previous step
10	Manually roll the quadrotor without losing sight of the beacons or translating the quadrotor	The reading shall not change from the previous step
11	Manually pitch and roll the quadrotor without losing sight of the beacons or translating the quadrotor	The reading shall not change from the previous step

4.3. Height Sensor Test

Objective

- Demonstrate accurate measurement of the height sensor
- Demonstrate the compensation of the measurement with the IMU data

Location

The dark corner of NSH B floor

Elements to be Tested

- Height sensor subsystem

Equipment

- Quadrotor
- Flat floor
- Measurement tap
- ROSbag software to record data

Personnel

Shu-Kai Lin

Procedure

1. Turn on the quadrotor and sensor suite
2. Launch all the necessary software nodes in ROS
3. Manually hold the quadrotor to the specific position (50 cm, 1m, 2m from the floor)
4. Record the measurement of the height sensor
5. Change the orientation of the quadrotor
6. Record the measurement of the height sensor
7. Repeat steps 4-6 at each position

Verification Criteria

1. The measurement error without orientation shall be less than 4cm
2. The measurement error with orientation shall be less than 7cm

4.4. Power Distribution Board Test

Objective

Demonstrate successful operation of power distribution board by ability to:

- Regulate input power down to 5V
- Hotswap batteries without loss of regulated power

Location

MRSD Lab Bench

Elements to be tested

- Power Distribution Board Rev.2

Equipment

- Power Distribution Board Rev.2
- Benchtop Power Supply
- Oscilloscope
- Voltmeter
- Quadcopter Battery

Personnel

Eitan Babcock, Ryan Gibbs, Samuel Wang

Procedure and Verification Criteria

	Description	Verification Metric
1	Plug in the battery to power distribution board	
2	Measure reading from 5V regulated output	Verify voltmeter measurement is within 1% of 5V
3	Probe 5V output with oscilloscope	Verify peak-to-peak is within .5V
4	Measure reading from 5V regulated output while plugging in 12V DC supply	Verify voltmeter measurement is within 1% of 5V Use oscilloscope triggering function to detect if there is a transient loss of power
5	Measure reading from 5V regulated output while unplugging battery	Verify voltmeter measurement is within 1% of 5V Use oscilloscope triggering function to detect if there is a transient loss of power
6	Measure reading from 5V regulated output while plugging in new battery	Verify voltmeter measurement is within 1% of 5V Use oscilloscope triggering function to detect if there is a transient loss of power
7	Measure reading from 5V regulated output while unplugging in 12V DC supply	Verify voltmeter measurement is within 1% of 5V Use oscilloscope triggering function to detect if there is a transient loss of power

4.5. Beacon Test

Objective

- Demonstrate beacon hardware emits correct pattern
- Demonstrate long and short range cameras read beacon emission pattern
- Demonstrate ROS node identification of beacon locations within a series of inertial frames with additional light sources

Location

B-level of NSH

Elements to be Tested

- Beacon circuit design
- Beacon Identifier node in ROS

Equipment

- Mock ship deck
- Beacons
- ROSbag software to record data
- Long-range camera
- Short-range camera

Personnel

Ryan Gibbs, Kelsey Ritter

Procedure and Verification Criteria

Demonstrate beacon hardware emits correct pattern

1. Connect beacon wiring to oscilloscope.
2. Turn on beacon power source.
    a. Verify on oscilloscope that power source is creating intended voltage pattern.
3. Turn off beacon power source.
4. Remove oscilloscope from beacon wiring.

Demonstrate that long and short range cameras read beacon emission pattern

1. Turn on beacon power source.
2. Run short range camera launch file on Odroid.
3. Use ROSbag to record 5 seconds of data without motion.
4. Stop camera image capture.
5. Run short range camera launch file on Odroid.
6. Use ROSbag to record 5 seconds of data without motion.
7. Stop camera image capture.
8. Turn off beacon power source.
9. Verify long and short range bag files
    a. Ensure camera frames capture images during and between all blinks of the beacons.

Demonstrate ROS node identification of beacon locations within a series of inertial frames with additional light sources

1. Turn on beacon power source.
2. Run short range camera launch file on Odroid.
3. Use ROSbag to record 20 seconds of data while rotating camera, keeping beacons within field of view of the camera.
4. Stop camera image capture.
5. Turn off beacon power source.
6. Verify bag files.
    a. Verify that strobe identification node accurately identifies locations of beacons within the image.

4.6. Optical Flow Test

Objective

Demonstrate accurate measurement of the optical flow sensor.

Location

Large open space

Elements to be Tested

- Optical flow sensor

Equipment

- Quadrotor
- ROSbag software to record data
- Laptop
- A car with cruise control

Personnel

Eitan Babcock, Shu-Kai Lin

Procedure

1. Bring all equipment into a car
2. Operate the optical flow sensor from the laptop
3. Drive the vehicle at a constant velocity using cruise control
4. Compare the measurement of the optical flow data with the constant velocity of the car

Verification Criteria

1. The measurement error shall less than 10%

4.7. Quadrotor State Estimator Test

Objective

- Demonstrate improved accuracy of state estimation
- Demonstrate improved update rate of state estimation
- Demonstrate the sensing
- robustness of using multiple sensors

Location

The dark corner of NSH B-level

Elements to be Tested

- Transformation subsystem
- Transformation nodes
- Sensor fusion subsystem
- Sensor fusion nodes

Equipment

- Mock ship deck
- Beacons
- Quadrotor
- Floor with artificial features
- ROSbag software to record data
- Laptop

Personnel

Eitan Babcock, Shu-Kai Lin, Samuel Wang

Procedure and Verification Criteria

1. Place the deck at the dark corner of NSH B floor
2. Turn on the power supply to power the beacons
3. Turn on the sensor suite
4. Launch the localization subsystems in ROS
5. Launch the transformation subsystems in ROS
6. Launch the sensor fusion subsystems in ROS
7. Manually hold the quadrotor and face the deck
8. Check the output reading of sensor fusion subsystem
    a. The reading error shall not exceed 10%.
    b. Measuring tape will be used to verify the readings.
9. Check the output update rate of sensor fusion subsystem
    a. The output update rate should be the prediction rate, which is the sampling rate of IMU
10. Block the camera and check the output reading
    a. The accuracy of reading would degrade but still output reasonable readings

4.8. Prediction Test

Objective

- Demonstrate accuracy of deck motion state estimator
- Demonstrate accuracy of prediction subsystem

Location

B-level of NSH

Elements to be Tested

- Deck state estimator
- Prediction subsystem

Equipment

- Light-weight cardboard (or similar) platform
- Beacons
- Quadrotor

Personnel

Eitan Babcock, plus any two available members of Team Kingfisher.

Procedure

1. Power on the beacons on the light-weight mobile platform
2. Power on quadrotor with all subsystems
3. Verify a bag file is collecting the following data:
    a. Robot state
    b. Deck state
    c. Prediction results
4. Manually take off and fly the quad such that the beacons are in view of the camera
5. Switch to autonomous hovering mode
6. Two people move the light-weight deck up in down in a periodic motion for at least 10 seconds
7. Retake manual control of the quad and land it safely
8. Power off quad and beacons

Verification Criteria

The bag file collected will be examined to determine if the test was successful. The following criteria must be met for the test to pass:

1. The motion of the deck is captured by the deck state estimator within 10cm.
    a. Note that the motion of the deck at this stage is produced by human input, so we do not have a reliable way to determine the actual state of the deck. For this reason, we can only determine if the deck state estimator appears to be working based on our human estimation of the deck's motion.
2. Safe landing times are predicted with 1.0 second accuracy at 10 seconds into the future.

4.9. Assembly/Layout Test

Objective

- Demonstrate manual flight with all hardware assembled
- Demonstrate operation of all hardware components

Location

MRSD Lab

Elements to be Tested

- Electrical layout of hardware
- Mechanical assembly of hardware

Equipment

- Small deck
- Quadrotor with following hardware assembled:
  - Mount frame
  - Short range camera
  - Long range camera
  - Power distribution board
  - IMU
  - RC converters
  - Height sensor
  - Optical flow sensor
  - Arduino Nano
  - Odroid

Personnel

Eitan Babcock, Ryan Gibbs, Shu-Kai Lin, Kelsey Ritter, Samuel Wang

Procedure

Demonstrate manual flight with all hardware assembled

1. Ensure all hardware is securely mounted in proper position and all electrical connections are in place.
2. Power on DJI and manual controller.
3. Using manual controller, take off from point 20m away from deck.
4. Manually fly DJI towards deck and land on deck.
5. Power down motors with manual command.
6. Turn off DJI and manual controller.
7. Verify that all components are still securely in their original positions, with all connections intact.

Demonstrate operation of all hardware components

1. Ensure that all of the assembly’s electrical connections are in place.
2. Connect HDMI cord between Odroid and monitor.
3. Power on DJI.
4. Verify that all powered components are receiving power.
5. Run a test node for each piece of hardware (simultaneously) to verify each is operational, using ROStopic echo:
    a. Height sensor
    b. Optical flow sensor
    c. Long range camera
    d. Short range camera
    e. Arduino nano
    f. IMU

Verification Criteria

1. No damage is done to the quadrotor, including all hardware and connections
2. All powered components operate from the quadrotor’s battery