Watson Capstone Projects

WCP09 Autonomous Beacon Location System (ABLS) Test Plan and Procedures

Lockheed Martin

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1 Scope

1.1 System Overview

The Autonomous Beacon Location System (ABLS) is a rover designed to locate a signaling beacon in the forest. The rover will be able to communicate with a base station regarding its location and surrounding, and map the path to the beacon. The rover will be capable of transmitting a first person video all the while autonomously navigating to the beacon. The rover will be controllable from the base station at any given time. This manual control will take precedence over any automatic control.

1.2 Document Overview

This integration and test plan outlines the various procedures and locations that will be used during the build of the system. Each test site is described, including the test being run, which component it is run on, and which team member is performing the test. Plans for the integration of different subsystems are also provided. Lastly, the procedures used to verify the requirements are given. These procedures can be duplicated to prove that the system requirements were met.

2 Referenced Documents

The following documents of the exact issue shown form a part of this document to the extent specified herein.

- WCP09 ABLS Project Specification, Rev. - of 28 September 2018

3 Integration and Test Environment

3.1 WCP Lab Test Site

This site will provide the most controlled test environment for the components. Here many of the more basic requirements will be verified. This site is important since it is safe and free from weather, obstacles, terrain, and other random factors an outdoor environment may have. This test site is suitable since it will test the basic functionality of the rover without dealing with difficult terrain and environment. The test site cannot have trees, rugged terrain, soil, rocks, or water. Advantages of the lab test site including 120V outlets, computers, oscilloscopes, power supplies, breadboards, and soldering equipment.

3.1.1 Hardware and Firmware Items

- Rover Chassis
- Infrared Sensors
- Ultrasonic Sensors
- Motor controller

- Radio Transmitters and Receivers
- Camera
- Beacon
- Batteries
- Battery Charger
- Bread boards
- Oscilloscope
- Multimeter
- Power supply
- Computer
- Dummy obstacles

3.1.2 Software Items

- Linux Operating System
- QGroundControl

3.1.3 Other Materials

- Wall power outlet
- HDMI display
- USB mouse
- Keyboard

3.1.4 Participants

All team members will be participating in the different unit tests. Electrical engineering students Joseph Bourque and Ethan Terwilliger will conduct hardware testing. Computer engineering students Henry Chen and Hao Sen Zheng will conduct software testing. Mechanical engineering student Jonathan Felder will conduct regression testing. For requirement verification testing, one person designated as the operator needs to have an amateur radio license. All participants should have a strong familiarity with the project/component under test, and one individual will be needed to assist in the transportation of the base station (laptop). Other personnel are not required but would be helpful.

3.1.5 Tests To Be Performed

- Hardware Testing
  - Testing the components we have received from the manufacturers to make sure they are working properly.
- Software Testing
  - This is used to make sure that all the software needed to operate our components are working correctly and communicating with said components.
- Integration Testing
  - Begin combining components into their subsystems and make sure they are not interfering with each other and communicating the correct information.
- Regression Testing
  - After each integration test we make sure that each components are

working the same as they had during our hardware testing.

- System Verification Testing
  - This is used to make sure we are meeting our requirements.

3.2 Open Field/Parking Lot

This test site will be used to prove that the rover can handle different terrain and weather conditions. This test location will be a step up from the lab. The lab contained no obstacles and a smooth floor. Here, we will start to introduce different terrains. This site is in essence a park or a parking lot which will give the system a simplified version of what the final test will entail. The site should include inclines, rocky areas, pavement, and sidewalks with puddles. The test site should not contain trees, large rocks, steep drop offs, and large bodies of water.

3.2.1 Hardware and Firmware Items

- Battery charger
- Multimeter
- Computer

3.2.2 Software Items

- Linux Operating System
- QGroundControl

3.2.3 Other Materials

- Power Source
- HDMI display
- USB mouse
- Keyboard

3.2.4 Participants

One computer engineering student, Henry Chen or Hao Sen Zheng, is needed to analyze proper movement of rover in correspondence to the navigation software and sensor readings. One operator with an amateur radio license is required to be present in accordance with the FCC regulations. One mechanical engineering student, Jonathan Felder, is needed to judge how the terrains are handled by the rover.

3.2.5 Test To Be Performed

- Static Testing
  - This is where we will place our rover on a block, leaving the wheels open and free off the ground so that we can test the full system is working together in locating the beacon and navigating towards it without any obstacles.
- Dynamic Testing
  - This is similar to Static Testing however, we will remove the block and place the rover on the ground and run the same test to make sure the full system is working together to locate the beacon and begin navigating towards it without any obstacles.

- System Verification Testing
  - This is used to test and see if our system is able to meet our requirements we have for various terrain.

3.3 Forested Area

The final tests will be completed in a forested area that will simulate the national park in which the system was designed to operate in. The forested area will include various terrains with steeper slopes, trees, fallen debris such as branches, rocks, and other potential obstacles. The main focus of this location is to test the obstacle avoidance algorithm of the system. At this point the rover should be able to handle all terrain and will be tested in a harsh environment under careful observation.

3.3.1 Hardware and Firmware Items

- Battery Charger
- Multimeter
- Computer

3.3.2 Software Items

- Obstacle Avoidance Algorithm
- Linux Operating System
- QGroundControl

3.3.3 Other Materials

- Power Source
- HDMI display
- USB mouse
- Keyboard

3.3.4 Participants

At least one operator is required for these tests, designated by holding an amateur radio license. One software engineering student, Henry Chen or Hao Sen Zheng, is also needed to follow the rover and verify the obstacle avoidance algorithm is working as designed. One electrical engineering student, Joseph Bourque or Ethan Terwilliger is required to ensure the beacon signal is being transmitted and received correctly.

3.3.5 Tests To Be Performed

- Static Testing
  - This is where we will place our rover on a block, leaving the wheels open and free off the ground so that we can test the full system is working together in locating the beacon and navigating towards it with the introduction of obstacles, such as trees, and bigger rocks.
- Dynamic Testing
  - This is similar to Static Testing however, we will remove the

block and place the rover on the ground and run the same test to make sure the full system is working together to locate the beacon and begin navigating towards it with the introduction of obstacles such as trees, and bigger rocks

- System Verification Testing
  - This is used to test and see if our system can handle various terrain the the introduction of bigger obstacles such as trees, and boulders.

4 System Integration

4.1 Integration Introduction

The ABLS is comprised of three subsystems. The most complex of which is the rover itself. The other two subsystems are the beacon and the base station. All three subsystems will be built simultaneously. The following section breaks down how the internal integration of each subsystem will be accomplished.

4.2 Rover

The rover has been broken down into five subsystems; drive, navigation, communication, camera, and power. The drive and power subsystems will be built and integrated first. This is done by connecting the Raspberry Pi to the TRex motor controller and the using the batteries to provide power for the rover. The test will then be to successfully control the rover’s movements through the Pi. As each new subsystem is integrated, the necessary power will be applied to it, adding batteries as necessary.

The navigation subsystem will be integrated next. This includes the integration of the obstacle avoidance algorithm and the beacon locating algorithm with the corresponding sensors and beacon signal receiver. There are two algorithms which will be built individually and tested individually on the rover with the drive system. The first will utilise information from the infrared and ultrasonic sensors to sense obstacles. The sensors must be correctly positioned and attached to the rover to provide accurate feedback and cover the 180 degrees in front of the rover. The second algorithm will use data from the beacon receiver to locate the beacon. The beacon signal receiver will be positioned on the rover such that it will be able to pick up the signal of the beacon. Then, the beacon signal receiver is to be tested with the navigation algorithm to show the algorithm is able to generate and update the directional goal based on the receiver’s feedback. The two algorithms with the needed sensors and receivers will then be integrated together to form the complete navigation algorithm.

The communication subsystem will be based on the core module that allows MavLink serial communication via radio frequencies between the Raspberry Pi and the base station. The communication software on both the Pi and PC will first be integrated with the radio transmitters and receivers. After the communication Link is established, the rest of the integration will be mostly in software. We will be able to track new messages that will be emitted from various modules into the communication link by creating new messages in Mavlink. Messages such as rover status and telemetry can be introduced to the system one by one as the other systems advance in their progress. Each new type of message will be introduced and tested with the previous functional messages to ensure they do not get confused with the old ones.

The camera subsystem does not interact with other subsystems on the rover, rather, it sends video feed straight to the base station to be displayed. To test this subsystem, we will display the live video feed on a monitor, sent over the high frequency transmitter and receiver pair that is each attached onto the rover and the basestation. This is the last integration step as it is fairly isolated from the rest of the system and just needs to be appropriately mounted upon the rover.

4.3 Beacon

The beacon itself is just a simple circuit with an radio frequency (RF) transmitter. The circuitry will need to be placed in a waterproof casing. There is no further integration that needs to take place within the beacon subsystem.

4.4 Base Station

The base station will be a laptop running a ground control software and a video player. The ground control software will provide a communication interface with the rover as well as a graphical interface that displays telemetry data received from the rover and the video player will display the first person footage sent by the rover’s camera subsystem. The ground control software does not require to be build. However, integration of the rover’s communication subsystem with the ground control software is required. The transmitters and receivers will be connected to the base station laptop using a serial to USB adapter. The video player will be working independently from the ground control software and will be integrated to the base station last.

4.5 Full System Integration

The final portion of the integration will be to merge all three major subsystems together. The three subsystems do not come into physical contact. The only connections between them are radio transmitters and receivers, allowing the different subsystems to communicate by sending messages to each other. These subsystems will be built simultaneously, with modules of each subsystem being build and then integrated together. Along the way, these integrations will be tested by checking the communications between the three subsystems.

5 System Verification

These qualification methods will be used in verifying that the project system meets all requirements in WCP09 ABLS Project Specification, Rev. - 28 September 2018

- Demonstration (D),
- Test (T),

- Analysis (A), and
- Inspection (I).

5.1 Test Coverage

Table 1 below shows where each test will be performed and which requirements it will verify. Appendix B shows a similar table with respect to each requirement in a Verification Cross Reference Matrix (VCRM).

Table 1: Test Information

Test ID	Test Name	Location	Requirements Verified	Dependencies
WCP09-T-001	System Inspection	Lab	19-23	none
WCP09-T-002	Connection Test	Lab	8, 9, 13, 14	wall outlet
WCP09-T-003	Beacon Test	Lab	4, 18	handheld radio
WCP09-T-004	Camera Test	Lab	10	wall outlet
WCP09-T-005	Simple Test	Lab	1, 11, 12, 15, 16, 24	oscilloscope, wall outlet
WCP09-T-006	Zero Obstacle	Open Park	2, 3, 6	box, handheld multimeter
WCP09-T-007	Full Mission	Forest	5, 7, 17	box, handheld multimeter

5.1.1 System Inspection (WCP09-T-01)

This group of tests will be used to verify requirements only by inspection, particularly requirements that do not require the system or subsystems under test to be powered on. This test have no dependencies of software and hardware tools and no requirements on test sites either.

5.1.2 Connection Test (WCP09-T-02)

The second group of tests will verify that the system is properly connection in terms of power and in terms of communication. The first test in this group will test that the power system is correctly delivering powers to each of the components as the rover is turned on. Then the following three tests will test that the vehicle and base station is able to initiate the communication channel between the rover and the base station.

5.1.3 Beacon Test (WCP09-T-03)

This group contains two tests. The first will verify that the beacon is complied with the FCC Rules. and the second component of the beacon test will demonstrates that the rover will react properly once it have detected the signal of the beacon.

5.1.4 Camera Test (WCP09-T-04)

This item contains only one test, which will verified that the system is able to capture and display a First Person Video of the vehicle.

5.1.5 Simple Test (WCP09-T-05)

This group of tests will verify the majority of the requirements. It will take place in the WCP Lab Test Site under controlled conditions. The main focus of this group of test will be to test the communications between the three major subsystems, as well as the subsystems on the rover itself. The test items of this test group includes demonstrations that shows the system is able to locate of a beacon. The vehicle will need to decide a general direction of the beacon when it is not close to the beacon. When the vehicle is close to the beacon, the vehicle will need to locate the location of the beacon. The group also included tests that demonstrates the rover's ability to communicate with the base station. Different from the connection test, in this test, the system will be tested in both sending data and receiving command to and from the base station after the start up.

5.1.6 Zero Obstacle (WCP09-T-06)

As mentioned in its name, this test will not test the obstacle avoidance algorithm. It will focus on other factors such as different terrains, slopes and weather conditions. The test is an intermediate step between the lab tests and a full scale version.

5.1.7 Full Mission (WCP09-T-07)

The final test will be a full mission run. This will simulate the mission that park rangers will run when the system is fully in use. The newest factor in this test are obstacles for the rover to avoid, mainly trees and fallen debris.

5.2 Test Schedule

March 22: Simple Test
March 29: Zero Obstacle
April 5: Full Mission
April 14: System Inspection

6 Notes

6.1 Acronyms and Abbreviations

ABLS - Autonomous Beacon Location System
RF - Radio Frequency
VCRM - Verification Cross Reference Matrix
WCP - Watson Capstone Projects

6.2 Bibliography

Any sources that were used to create this document will be listed in the Design Report and Project Report.

Appendices

Appendix A

System Verification Tests

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[First Test Group]

Overview

<Insert here>

Test Procedures

<Project-unique test identifier> <Name of first test>

<Insert here>

Appendix B

Verification Cross Reference Matrix

Requirement	Summary	Method	Test Location	Test ID	Test Name
WCP09-R-001	Autonomously locate hidden beacon	D	Lab	WCP09-T-005	Simple Test
WCP09-R-002	Autonomously navigate to hidden beacon	D	Forest	WCP09-T-007	Full Mission
WCP09-R-003	Mapping of location and directional path of vehicle	D	Forest	WCP09-T-007	Full Mission
WCP09-R-004	Notify operator if beacon signal was received	D	Lab	WCP09-T-003	Beacon Test
WCP09-R-005	Minimum 20 minute operating time	T	Field	WCP09-T-006	Zero Obstacle
WCP09-R-006	Navigating around obstacles	D	Forest	WCP09-T-007	Full Mission
WCP09-R-007	Durable enough to handle various terrains	D	Field	WCP09-T-006	Zero Obstacle
WCP09-R-008	ABLS's component shall be powered when power switch is flipped on	D	Lab	WCP09-T-002	Connection Test
WCP09-R-009	After vehicle system is powered on, it shall attempt to search and connect with the base station	D	Lab	WCP09-T-002	Connection Test
WCP09-R-010	First person View of vehicle	D	Lab	WCP09-T-004	Camera Test
WCP09-R-011	Display Telemetry data on base station	D	Lab	WCP09-T-005	Simple Test
WCP09-R-012	Telemetry data includes distance beacon from rover,	I	Lab	WCP09-T-005	Simple Test
WCP09-R-013	Upon initial startup, GUI shall await initial message from vehicle	D	Lab	WCP09-T-002	Connection Test
WCP09-R-014	Base Station shall acknowledge vehicle's search message upon	D	Lab	WCP09-T-002	Connection Test

	receiving to establish connection				
WCP09-R-015	Base station shall transmit start command to vehicle when operator selects the start option on GUI	D	Lab	WCP09-T-005	Simple Test
WCP09-R-016	The vehicle shall start its mission after it receives the start command from Base station	D	Lab	WCP09-T-005	Simple Test
WCP09-R-017	The vehicle shall enter manual control mode upon receipt of an override command	D	Field	WCP09-T-006	Zero Obstacle
Requirement	**Summary**	**Method**	**Test Location**	**Test ID**	**Test Name**
WCP09-R-018	FCC Rules compliance	T	Lab	WCP09-T-003	Beacon Test
WCP09-R-019	FAA Rules compliance	I	Lab	WCP09-T-001	System Inspection
WCP09-R-020	System shall be either ground based or air based	I	Lab	WCP09-T-001	System Inspection
WCP09-R-021	Amateur radio license	I	Lab	WCP09-T-001	System Inspection
WCP09-R-022	System safety manual	I	Lab	WCP09-T-001	System Inspection
WCP09-R-023	System operators manual	I	Lab	WCP09-T-001	System Inspection
WCP09-R-024	Locate direction of the beacon	D	Lab	WCP09-T-005	Simple Test