# Autonomous Organic Crop Monitoring

Fall Test Plan

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# 2. Introduction

This document outlines Wholesome Robotics' plans for validation testing over the course of the upcoming semester. Throughout the semester we will be testing individual subsystem parts and presenting our success on a component level. At the end of the semester, we will demonstrate the completed and integrate system, with a test that uses all of the subsystems to fulfill the use case specified to our customer.

# 3. Logistics

Field Visit Checklist

Through our experience at previous field tests, we have completed a pretest checklist to use prior to any trip to Rivendale Farms. This checklist is used for each test that indicates Rivendale Farms as our location, as well as any other trips, such as those for intermediate testing or data collection:

**Robot Hardware + Sensors/ Cameras**

- ❑ Custom stereo camera working
- ❑ Camera mounts + Robot hardware in place

**Battery/Power**

- ❑ Power Generator
- ❑ Fuel refilled in generator
- ❑ Robot battery charged
- ❑ Robot battery charger
- ❑ RC battery charged/ replaced

**RTK GPS**

- ❑ GPS cables
- ❑ RTK GPS communication pre-tested and working

**Rivendale + Transportation**

- ❑ Weather acceptable
- ❑ The vehicle booked for the duration of field test
- ❑ Tarpaulin Sheet packed

# 4. Schedule

| Progress Review | Capability Milestones | Associated Tests | Associated Requirements |
|---|---|---|---|
| #8 (9/25) | • Visualizer V1 complete<br>• RTK Node complete | | |
| #9 (10/9) | • MVP of Monitoring complete<br>• Localization integrated<br>• Camera exposure v1 complete | Test 05 | MN1,2 |
| #10 (10/23) | • Navigation MVP complete | Test 03, 04, 07 | MR 3,4,5,6 (MR 6.1 - 6.4) |
| #11 (11/6) | • Wheel covers installed | Test 01, 02, 06 | MR 1, MR 2<br>MN 4 |
| #12 (11/18) | • Integration and Testing | | |
| FVD (11/25) | • Full system integration | Test 08 | MR 1-6<br>MN 1-4 |

**Note:** Generally, tests are scheduled for the PR after the capability milestone has been achieved to leave room for finishing touches and dry runs before presenting the results.

# 5. Tests

| **Test Number:** | 01 | **Test Name:** | Autonomous Navigation Test | **Test Date:** | 11/6 |
|---|---|---|---|---|---|
| **Objective:** | Autonomously traverse field without hitting plant stem (MN4, MR1, MR2) | | | | |
| **Elements Tested:** | Subsystem: Autonomous Row Navigation | | | | |
| **Location:** | Rivendale Farms - Recorded on Video | | | | |
| **Equipment:** | ● See field visit checklist<br>● Map of the field<br>● Cameras | | **Personnel:** | ● Team E<br>● Rivendale farm representatives (Not required) | |
| **Procedure:** | 1. Place the robot at the start of the first row<br>2. Command the robot to start autonomous navigation<br>3. Robot traverses the row and switches to the next row<br>4. The robot stops after traversing 5 rows | | | | |
| **Verification Criteria:** | ❑ Robot does not hit plant stems while navigating<br>❑ Robot successfully switches row 4 out of 5 times | | | | |

| **Test Number:** | 02 | **Test Name:** | Coverage Planner Test | **Test Date:** | 11/6 |
|---|---|---|---|---|---|
| **Objective:** | Verify coverage plan covers the entire field of interest | | | | |
| **Elements Tested:** | Subsystem: Coverage Planner | | | | |
| **Location:** | Newell Simon Hall | | | | |
| **Equipment:** | • Map File<br>• Computer | | **Personnel:** | • Team E<br>• MRSD Advisors | |
| **Procedure:** | 1. Load the map file<br>2. Software generates the coverage plan<br>3. Play animation showing the entire coverage plan | | | | |
| **Verification Criteria:** | ❏ Coverage planner covers the rows of interest that the robot can reach | | | | |

| **Test Number:** | 03 | **Test Name:** | Pest/Disease Perception Software Test | **Test Date:** | 10/23 |
|---|---|---|---|---|---|
| **Objective:** | Evaluate the performance of plant health monitoring deep net (MR4, MR5) | | | | |
| **Elements Tested:** | Subsystem: Mask-RCNN (Perception) | | | | |
| **Location:** | Newell Simon Hall | | | | |
| **Equipment:** | ● Server with GPU<br>● Test images (labeled {positive, negative}) from a new spatial area of the field, on which we have not trained before | | **Personnel:** | ● Team E<br>● MRSD Advisors | |
| **Procedure:** | 1. Power on gpu server<br>2. Run plant health model inference<br>3. Software loads test images and computes performance metric | | | | |
| **Verification Criteria:** | ❑ Robot successfully identifies fungus and holes with greater than 80% precision and recall with unhealthy defined as positive<br>* precision = Tp / (Fp + Tp), recall = Tp / (Fn + Tp) | | | | |

| **Test Number:** | 04 | **Test Name:** | Visualization Subsystem Test | **Test Date:** | 10/23 |
|---|---|---|---|---|---|
| **Objective:** | Evaluate the speed of monitoring pipeline and GUI Features (MR6) | | | | |
| **Elements Tested:** | Subsystem: Monitoring pipeline | | | | |
| **Location:** | Newell Simon Hall | | | | |
| **Equipment:** | ● GPU Server<br>● Pre-recorded ROS bag files of the entire rows of interest | | **Personnel:** | ● Team E<br>● MRSD Advisors | |
| **Procedure:** | 1. Power on GPU server<br>2. Run visualization pipeline<br>3. Software loads test images and visualizes the results in GUI<br>4. Visually demonstrate the field's layout<br>5. Select a datapoint and change the classification, to demonstrate change in the stored data<br>6. End the visualizer and relaunch it to show the same data | | | | |
| **Verification Criteria:** | ❏ Robot successfully processes data at a rate faster than one field per 24 hours (MR 6)<br>❏ Clear depiction of the field layout and data presentation (subjective)<br>❏ Successful use of interactive portions of the GUI<br>❏ Successful data preservation on relaunch | | | | |

**Note:** The GUI features are subject to change, pending product reviews with the farmers

| **Test Number:** | 05 | **Test Name:** | Robot Platform Verification | **Test Date:** | 10/9 |
|---|---|---|---|---|---|
| **Objective:** | Verify Non-Functional Requirements related to the Robot Platform (MN1, MN2) | | | | |
| **Elements Tested:** | Subsystem: Robot Platform | | | | |
| **Location:** | Rivendale Farms | | | | |
| **Equipment:** | ● Video Camera<br>● Robot<br>● Tape Measure | | **Personnel:** | ● Team E<br>● MRSD Advisors | |
| **Procedure:** | 1. Power on robot<br>2. Drive the robot via joystick<br>3. Continue to press on joystick, releasing the remote kill switch, demonstrating a stop<br>4. Drive the robot via joystick<br>5. Press the mechanical E-Stop to demonstrate a stop<br>6. Drive the robot to the beginning of the first row of the brassica field<br>7. Measure the open space between the robot and the plant stems, to demonstrate plant clearance | | | | |
| **Verification Criteria:** | ❏ Effectiveness of remote kill switch<br>❏ Effectiveness of mechanical E-stop<br>❏ Fit of robot into field's rows | | | | |

| **Test Number:** | 06 | **Test Name:** | Battery Life Test | **Test Date:** | 11/6 |
|---|---|---|---|---|---|
| **Objective:** | Confirm battery life is sufficient for the Rivendale Brassica Field (MN3) | | | | |
| **Elements Tested:** | Subsystem: Robot Platform | | | | |
| **Location:** | Rivendale Farms | | | | |
| **Equipment:** | • Robot<br>• Video camera | | **Personnel:** | • Team E<br>• MRSD Advisors | |
| **Procedure:** | 1. Place the fully charged robot at the start of the first row<br>2. Drive the robot at standard speed, through the entire brassica field | | | | |
| **Verification Criteria:** | ❑ Sufficient Battery Life to cover the entire brassica field | | | | |

| **Test Number:** | 07 | **Test Name:** | Usable row images | **Test Date:** | 10/27 |
|---|---|---|---|---|---|
| **Objective:** | Confirm that we are collecting images of acceptable exposure which are usable for the deep learning pipeline. (MR3) | | | | |
| **Elements Tested:** | Subsystem: Mask-RCNN (Perception) | | | | |
| **Location:** | Newell Simon Hall | | | | |
| **Equipment:** | • ROS Bag<br>• ROS-enabled laptop | | **Personnel:** | • Team E<br>• MRSD Advisors | |
| **Procedure:** | 1. Take a ROS Bag consisting of left and right camera images collected from a row traversal as input.<br>2. Use the exposure testing script to process images and find the percentage of images that pass an over/underexposed test. | | | | |
| **Verification Criteria:** | ❑ The percentage of images that pass the test should be > 75% | | | | |

| **Test Number:** | 08 | **Test Name:** | System Integration Test | **Test Date:** | 11/25 |
|---|---|---|---|---|---|
| **Objective:** | Verify end-to-end robot system functionality ( MR 1-6, MN1-4) | | | | |
| **Elements Tested:** | Robot Platform, Navigation, Plant Health Monitoring, GUI | | | | |
| **Location:** | Rivendale Farms / Newell-Simon Hall | | | | |
| **Equipment:** | Rivendale Farms<br>● Video Camera<br>● Robot<br>● Joystick<br>● Portable hard drive<br><br>Newell-Simon Hall<br>● Server with GPU | **Personnel:** | ● Team E (Rivendale Farms)<br>● MRSD Advisors (Newell-Simon Hall) | | |
| **Procedure:** | 1. Set up video camera and begin recording<br>2. Complete Test 01 Autonomous Navigation Test<br>3. End recording of video<br>4. Copy the ROS bag from the plant health monitoring run to the portable hard drive<br>5. Transport the hard drive to the MRSD lab and copy files to server for inference<br>6. Run Test 07 Usable Row Images Test on server<br>7. Run Test 03 Pest/Disease Perception Software Test<br>8. Complete Test 04 GUI Feature Verification for this new data | | | | |
| **Verification Criteria:** | ❏ Video correctly shows criteria for Test 01, Autonomous Navigation passed<br>❏ Collected data passes Test 07 Usable Row Images test<br>❏ System passes Test 03 Pest/Disease Perception Software Test on newly collected data<br>❏ System passes Test 04 GUI Feature Verification on newly collected data | | | | |

# Appendix

System Performance Requirements:

MR1. Autonomously Navigate within the row
- MR1.1. In the correct row with 80% accuracy
- MR1.2. Cross track control error < 3 in within the row

MR2. Autonomously switch between rows of the field with 80% success rate

MR3. Collect visual data with 75% images with correct exposure

MR4. Identify signs of disease on plant with precision and recall > 80%

MR5. Identify pests and /or signs of pests with precision and recall > 80%

MR6. Generate meaningful reports within 24hrs of collection
- MR6.1. Label row with plant name
- MR6.2. Label image with severity level
- MR6.3. Allow user to see and change the severity level
- MR6.4. Show date of monitoring on the GUI

System Non-Functional Requirements:

MN1. Fit in the row of width 24in // tested via autonomous navigation

MN2. Accommodate various control modes via kill switch and joystick

MN3. Have sufficient battery life to complete a run of Rivendale brassica field

MN4. Not damage plant during navigation