LPARD-TDF-2012

Lafayette Programmable Autonomous River Droid Tracking and Data Fusion

ECE492 - Spring 2012

Acceptance Test Plan

Last Revision Date 4/16/2012
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Purpose

To ensure that our designed system meets all the requirements as specified in the LPARD-TDF-2012 Statement of Work, this document will provide the tests and measurements that will be carried out to prove the system meets requirements. Each test will outline a testing scenario that provides the materials needed and location where the test is to be executed. Included with each test will also be a procedure and a specific list of requirements that the test will verify.

Acceptance Testing

Acceptance Test T001 - Sensor Functionality:
This test represents partial completion of our positioning requirements R000 and R001.

Required Materials (Other than the system):
- Extension cord (2 x 25’, 1 x 50’, 1 x 100’)
- 18V AC Adaptor (3x total - to power each tripod sensor and the boat’s circuitry).
- Power Strip (1x with at least 5 slots)
- Tape Measure (length of 50’ or greater)
- Lab chair (to place boat circuitry on same height as tripod’s height)
- Masking Tape to mark locations on ground
- Laser pointer

Ultrasound Procedure (Refer to Figure 1 for scenario):
1. Take the equipment out to the long hallway on the fourth floor of AEC.
2. Plug a power-strip into wall outlet.
3. Open up the GUI program and power up/ connect the tripods to the laptop according to the User’s Manual.
4. Manually place the AZEL servos in a neutral position so that the ultrasound sensors point directly down the hallway and parallel to the ground (use laser pointer to assist). Set up both tripods at a height of three feet (measured from the bottom of the ultrasound sensor to the ground.
5. Place the tripods a distance of approximately 11 tiles apart from one another (5 meters) and have the ultrasound sensors facing each other. (When placing
the tripods, position them such that the front of the ultrasound is as close to directly above the edge of the floor tile as possible by eye).

6. Plug 5 meters into the sound calibration distance and press the speed of sound button, which calibrates only the speed of sound and does not lock onto the boat.

7. Move one tripod out of the way since its data will not be used (for the purpose of this test we are showing that a range can be generated, so only one tripod is needed).

8. Plug in the boat’s circuitry and place it on top of a lab chair (adjust lab chair height such that the bottom of the ultrasound sensor is at three feet high).

9. Mark the ground with a tape marker at 11 tile increments from the base tripod with tape (11 tiles is 5.029 meters) out to 55 tiles (just past 25 meters).

10. Place the chair (with ultrasound sensor at the tile edge line) at the first tape mark and let sit for 15 seconds. Repeat this process for each tape marker (see Figure 1 for a diagram of the testing setup).

11. Once complete, stop recording data and open the Ranging CSV file to see the recorded range values.

**Criteria for Success:** For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS range with a 90% confidence interval. If this value is less than 14 cm off the expected range, then the test is successful.

Sample standard deviation: \( \sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1} \), where \( x_i \) is the \( i^{th} \) measured range and \( \bar{x} \) is the expected distance, and \( n \) is the number of samples taken

\[ C = \chi^2(n \cdot .90) = 4.865 \]

Confidence Interval @ 90% for \( \sigma^2 \):

\[ \left[ 0, \frac{(n-1)\sigma_s^2}{4.865} \right] \]

Eq1: \( x_{\text{RMSConfidence}} = \sqrt{\bar{x}^2 + \sigma^2} \)

5m-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____
Xrms computed by Eq1: 

10m-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: 

15m-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: 

20m-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: 

25m-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: 

Pass: ___________ Fail: ___________

Diagram of Test T001 Scenario
Figure 1
IR Azimuth Procedure (Refer to Figure 2 for scenario):

1. Take the equipment out to the long hallway on the fourth floor of AEC.
2. Plug a power-strip into wall outlet.
3. Open up the GUI program and power up/connect the tripods to the laptop according to the User’s Manual.
4. Manually place the AZEL servos so that they IR lens is pointing directly at the IR beacon on the boat PCB.
5. Place the boat beacon on a lab chair such that it can be easily maneuvered around, and adjust the height of the tripod such that the photodetector and beacon are on relatively the same level.
6. Using a tape measure and tape, measure out 15’ straight out from the IR detector while it is in neutral position and place the a piece of tape. As shown in Figure 2, measure and place a piece of tape at 1’,3’,5.25’. Repeat for 60’ as but put the tape locations at 5’, 10’, and 21.5’ as shown in Figure 2.
7. Place the boat at the 15’, zero degrees mark and face the beacon towards the IR photodetector. Press the IR “lock on” button on the GUI such that the IR photodetector is locked onto the boat beacon (explained in the IR section of the User’s Manual).
8. Log the azimuth angle displayed in the GUI log, move the boat circuitry away from the taped location, then place back at the taped location. Repeat this until you have 10 measurements and then move onto the next location.

Note: the 15’ test shows that the azimuth works and the 60’ test shows that the azimuth works at a range.
Figure 2

Criteria for Success: For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS azimuth angle with a 90% confidence interval. If this angle is less than 1 degree off from the expected value, then the test is successful.

Sample standard deviation: \( \sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1} \), where \( x_i \) is the \( i^{th} \) measured angle and \( \bar{x} \) is the expected angle, and \( n \) is the number of samples taken.

\[
C = \chi^2(n) (.90) = 4.865
\]

Confidence Interval @ 90% for \( \sigma^2 \):

\[
\left[ 0, \frac{(n - 1)\sigma_s^2}{4.865} \right]
\]

Eq1: \( \chi_{RMS\text{Confidence}} = \sqrt{\bar{x}^2 + \sigma^2} \)

3.81 degrees at 15°:

10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: _________
11.31 degrees at 15’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

19.29 degrees at 15’:
10-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-3.81 degrees at 15’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-11.31 degrees at 15’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-19.29 degrees at 15’:
10-points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

9.46 degrees at 60’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

19.71 degrees at 60’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-9.46 degrees at 60’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-19.71 degrees at 60’:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____
Equation 1: __________

Pass: ___________  Fail: ___________

**IR Elevation Procedure (Refer to Figure 3 for scenario):**

1. Take the equipment out to the long hallway on the fourth floor of AEC.
2. Plug a power-strip into wall outlet.
3. Open up the GUI program and power up/connect the tripods to the laptop according to the User’s Manual.
4. Set up the tripods such that the AZEL is mounted at a 90 degree angle to the floor (mount the AZEL such that the normal azimuth angle is now the elevation angle).
5. Place the boat beacon on a lab chair such that it can be easily maneuvered around, and adjust the height of the tripod such that the photodetector and beacon are on relatively the same level.
6. Measure out 15’ from the IR photodetector while the AZ/EL is in a neutral position. Place a piece of tape on the ground and then mark off 1’, 3’, 9’, and the other locations marked in Figure 3 that are perpendicular to the 15’ line.
7. Place the boat beacon at the end of the 15’ line and point it directly towards the IR photodetector.
8. Press the IR “lock on” button on the GUI such that the IR photodetector is locked onto the boat beacon (explained in the IR section of the User’s Manual).
9. Move the boat to each of the taped off locations and let boat sit for approximately 15 seconds.
Criteria for Success: For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS elevation angle with a 90% confidence interval. If this value is off from the expected angle by less than 1 degree, then the test is successful.

Sample standard deviation: \( \sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{10 - 1} \), where \( x_i \) is the \( i^{th} \) measured angle and \( \bar{x} \) is the expected angle, and \( n \) is the number of samples taken.

\[
C = \chi^2_{(n)(.90)} = 4.865
\]

Confidence Interval @ 90% for \( \sigma^2 \):

\[
\left[ 0, \frac{(n - 1)\sigma^2_s}{4.865} \right]
\]

Eq1: \( x_{RMSConfidence} = \sqrt{\bar{x}^2 + \sigma^2} \)

11.31 degrees:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: ________

Figure 3
45 degrees:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

$X_{rms}$ computed by Eq1: _________

69.68 degrees:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

$X_{rms}$ computed by Eq1: _________

Pass: ____________  Fail: ____________
Acceptance Test T002 - SCADA

Requirements Verified:
- R002-1, 2, 4, 6, 7, 8, 9, 13
- R003-1
- R004-2, 3, 4
- R005-1
- R006-1, 2

Required Materials:
- Simulation Software

Procedure:

1. Set up the laptop, LPARD Shore Interface box, Arduino, and Power Supply on center table according the User’s manual in AEC 400
2. Check that all cables are correctly connected according to User Manual
3. Place LPARD Boat Hardware on lab desk near whiteboard.
4. Load simulation software on hardware(sensor tripods will contain simulation protocol - tracking will be irrelevant)
5. Turn on laptop.
6. Start the LPARD software - the GUI will open.
7. Click: File->New Session - new session window will open
8. Enter user name as “Test002Boat”, location as “AEC 400”, and the baseline distance as 1m in prompt, check boat simulation mode and hit OK.
9. Turn on boat and hit Calibrate. The GUI will open.
10. Change the control mode from Autonomous Freeze (the default) to Autonomous Ferry.

11. Verify that a Ferry input of +5x, +5y(absolute) correctly simulates that the boat reaches that position.

12. Upon completion of command, boat should return to autonomous freeze.

13. Verify that a Ferry input can no longer be entered.

14. Repeat steps 10, 11, 12, 13 but instead use a mouse click to designate a ferry point to return to origin in step 11.

15. Click on the “Script” button and input a combination of freezes and ferries in the specified input and verify that the script runs (the commands are affirmed through simulation).

16. Verify that the graph correctly displays the updating x vs y position and the heading.

17. Navigate to log file directory on laptop and verify that data from the test session has logged correctly for: each sensor, initial polar to Cartesian position conversion, fused position value, and the system commands and faults.

18. Enter user name as “Test002Sensors”, location as “AEC 400”, and the baseline distance as 1m in prompt, check sensor simulation mode and hit OK.

19. Navigate to the model file directory on the laptop and open “sensor_model.cfg”. Check to see that the fields time=18, AZ=60, EL=45.

20. Verify that the GUI displays the position of the boat at x=3.00, y=5.19.

21. Power down the boat’s micro-controller and verify that the boat is no longer connected to the system and both the GUI and the log file for the system log this fault.

22. Once finished, power down the boat, then close the program, then power down the laptop.

R002-1: Show SCADA supports all the operating and maintenance modes.

**Criteria for Success: SCADA supports the following modes: sensor calibration, acquisition, tracking, changes in control mode, default mode with loss of data link; while logging of all data.**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Pass:</th>
<th>Fail:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Calibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acquisition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change to Ferry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change to Freeze</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Enter Default -  

Pass: __________  Fail: __________

R002-2: Show SCADA serves as the Operation User Interface for autonomous control.

Criteria for Success: Success will be determined if the mode can be changed and then verified through simulation of the boat. All of the mode changes run should be logged in the laptop software’s system log and can be verified by checking its respective CSV file.

Pass: __________  Fail: __________

R002-4: Show SCADA UI allows a trained human technician to easily control and monitor the processes.

Criteria for Success: Will be verified by end user input in the form of feedback to evaluate our final user that caters to ease of use.

R002-6: Show the following parameters are monitored and stored by SCADA: boat position and orientation, raw position sensor data, hydrology sensor data, voltage, current, and power delivered by power supplies, subsystem temperatures, and operational state.

Criteria for Success: If a separate CSV file with session data has been created for: each sensor, initial position fusion from polar to Cartesian, and completely fused position displayed in the GUI. This can be verified by a non-existent directory before session use, as well as an affirmation of after session use by means of checking each file is present and that it contains correct data other than header information.

Pass: __________  Fail: __________

R002-8: Show plots over specified parameter ranges can be generated by the user.

Criteria for Success: Success will be determined by demonstrating an ability to use Microsoft Excel to generate a plot of two arbitrary sensor CSV log files that are stored in the session directory.

Pass: __________  Fail: __________

R002-9: Show the SCADA logs commands, events, exceptions, faults, and operation state changes.
**Criteria for Success:** Success will be determined if the system log has been generated for the test session. The program will log all data displayed in the GUI under system output which will contain all the parameters listed above. All system events displayed should be recorded by hand and compared with the logged information to verify a correct log file. Additional information may be logged and should not preclude success of this requirement being demonstrated.

**Pass:** __________  **Fail:** __________

R002-13: Show the SCADA can automatically log an event, enable an alarm, and declare a fault to shutdown the system.

**Criteria for Success:** Success will be determined if the fault (lost connection to boat by turning off its micro-controller) tested is affirmed in the system log and displayed on the GUI.

**Pass:** __________  **Fail:** __________

R003-1: Show the LPARD includes an autonomous closed loop controller that interfaces with the shore based RC link for propulsion and maneuvering.

**Criteria for Success:** Instructor signs off on requirement being waived.

**Pass:** __________  **Fail:** __________

R004-2: Show freeze mode can be supported by the existing software.

**Criteria for Success:** Success will be determined by the successful system logging of freeze mode and simulation holding boat position.

**Pass:** __________  **Fail:** __________

R004-3: Show ferry mode can be supported by the existing software.

**Criteria for Success:** Success will be determined by the successful system logging of ferry mode (with its designated inputs) and simulation reaching those inputs.

**Pass:** __________  **Fail:** __________

R004-4: Show script mode can be supported by the existing software.
Criteria for Success: Success will be determined by the successful system logging of the script that is run and simulation reaching those inputs.

Pass: ___________ Fail: ___________

R005-1: Show full-duplex communication by having real time data appear on both sides of the RF link at the same time.

Criteria for Success: During step 18, real time data appeared on the GUI and the Terminal display.

Pass: ___________ Fail: ___________

R006-1: Show real time display of relevant information.

Criteria for Success: Success will be determined if the GUI implements R006-2 at the rate of data recording, which by default will be once per second.

Pass: ___________ Fail: ___________

R006-2: Show both numeric and graphical representations.

Criteria for Success: Success will be determined by the presence of a graphical situational representation in the GUI. In addition, GUI will also have a field allocated for position, sensors on the boat, and a field for payload sensors. Each will contain numerical representations of any sensor listed.

Pass: ___________ Fail: ___________
Acceptance Test T003 - Sensor Fusion:

This test verifies the following requirements:

- R000-1,2,3
- R001-1,2,3
- R005-2

Required Materials (other than the system itself):

- Extension cord (2x 25’, 1x 50’ 1x 100’)
- 18V AC Adaptor (3x total - to power each tripod sensor and the boat’s circuitry).
- Power Strip (1x with at least 5 slots)
- Tape Measure (length of 50’ or greater)
- Fold up table to place laptop on.
- Masking Tape to mark locations on ground
- Laser pointer

Procedure:

1. Take all required equipment out to the test site.
2. Plug in a 50’ extension cord to wall outlet and plug a power strip to the end. This power strip will represent the AC main from which we draw our maintenance mode power.
3. Setup the system according to the User’s Manual.
4. Place a piece of masking tape at position approximately half way between the two tripods and a distance of approximately two meters from the baseline distance (this will represent the origin point of our local coordinate system).
5. Using the measuring tape, locate the positions marked out by the red dots on Figure 4 below (we estimate 2 cm error in both x and y from this measurement).
6. Place the boat’s visual beacon at the origin and the boat’s heading facing directly towards P3 so that P3 represents zero degrees. Calibrate system according the User’s Manual.
7. Rotate the boat so that the heading is facing each of the points marked (use laser pointer to assist). Let the boat sit for 10 seconds, then repeat process for each point.
8. After each location has been marked, turn the power switch on the boat so that the boat is powered on and move the boat to the marked locations (place the boat on the ground with the lighting beacon directly on top of the tape and the ultrasonic sensor facing one of the two beacons).
9. Allow boat to sit at each position for about fifteen seconds so that the SCADA program can log at least 10 (x,y) positions of the boat. Move the boat to each position marked by tape and repeat.

**Diagram of Test T003 Scenario**

**Figure 4**

R000-1: Shows that our system can continuously calculate 2D Cartesian coordinates relative to an absolute Earth Coordinate System.

*Criteria for Success:* The value of (x,y) position of the boat displayed by the GUI changes as the boat is moved from one position to another (assuming that the mover does not block the sensors).

*Pass:* ____________  *Fail:* ____________
R000-2: Show that the calculated position of the boat is accurate to within the required 10 cm RMS value.

Criteria for Success: For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS x,y position with a 90% confidence interval. If the x and the y value resulting from this equation for each location is has less than 20 cm error, then the test is successful.

Sample standard deviation: \( \sigma_s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{10-1} \), where \( x_i \) is the \( i \)th measured position and \( \bar{x} \) is the expected position, and \( n \) is the number of samples taken.

\[
C = \chi^2_{(n),(.90)} = 4.865
\]

Confidence Interval @ 90% for \( \sigma^2 \):

\[
\left[ 0, \frac{(n-1)\sigma^2_s}{C} \right]
\]

Eq1: \( x_{RMSConfidence} = \sqrt{\bar{x}^2 + \sigma^2} \)

\( x,y \) at P1:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

\( x,y \) at P2:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

\( x,y \) at P3:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

\( x,y \) at P4:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________
x,y at P5:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

Pass: ___________ Fail: ____________

R000-3: System provides continuously updated estimates of the boat heading relative to the same coordinate system used in R000-1 with an uncertainty less than 0.25 degree RMS.

Criteria for Success: For each angle, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS angle with a 90% confidence interval. If the angle error resulting from this equation for each location is below the proposed 1.5 degrees, then the test is successful.

90°:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

45°:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

0°:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-45°:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-90°:
10 points: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____
Xrms computed by Eq1: __________

Sample standard deviation:

\[
\sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1},
\]

where \( x_i \) is the \( i \)'th measured angle and \( \bar{x} \) is the expected angle, and \( n \) is the number of samples taken.

\[
C = \chi^2_{(n)} (.90) = 4.865
\]

Confidence Interval @ 90% for \( \sigma^2 \):

\[
\left[ 0, \frac{(n - 1)\sigma_s^2}{4.865} \right]
\]

Eq1: \( \chi_{RMSConfidence}^2 = \sqrt{\bar{x}^2 + \sigma^2} \)

Pass: ___________  Fail: ___________

R001-1: Position estimates are accurate to values specified in R000-2 and R000-3 over a 5 to 25 meter range.

Criteria for Success: If the positions measured in R000-2 are within the proposed 20 cm value (analysis given in the document Error Analysis), and both the IR and ultrasound sensors have proven 25 meter range via Test001.

Pass: ___________  Fail: ___________

R001-2: Position estimates are accurate to values specified in R000-2 and R000-3 over a ± 90 degree in azimuth from the shore station.

Criteria for Success: Points P1 and P5 labeled in Figure 1 (if placed at the labeled positions), shows a ~ ±83 degree operational swath. If points P1 and P5 are measured successfully in R000-2, then these points therefore meet the operational swath requirements.

Pass: ___________  Fail: ___________

R001-3: Degraded accuracy shall be possible over a swath out to 200 meters in range.
Criteria for Success: As long as the GPS is sending data to the GUI program over the laptop via the RF link, we will have “degraded accuracy” by means on the GPS position. The requirement is therefore successful if the GUI program on the laptop displays the GPS value and the provided analysis (shown in document RF Distance Analysis) shows that our RF link is capable of communicating over 200 meters (200m QA test for RF is impractical).

Pass: ___________    Fail: ___________

R005-2: Data link does not interfere with signals used for positioning.

Criteria for Success: Success criteria for R000-2 and R000-3 have been met - as there is position data being transmitted to the boat (shore sensors) and to the shore (fused position), meeting those requirements implies the data link does not interfere.

Pass: ___________    Fail: ___________

**Detailed System Requirements**

The following requirements represent the final project requirements for the LPARD-TDF-2012 system. If any requirement within the original scope of work is not achievable within or applicable to the 14 week schedule, the required documentation will be referenced within that requirement. The following are the agreed upon and altered requirements adapted from the LPARD-TDF-2012 Statement of Work as on the last revision date of this document noted at the bottom of the title page. No requirements can be modified without the explicit agreement of the ECE492 Faculty.

**R000: Position and Heading Estimates**

1. Continuously updated estimate of the 2D (x/y) position of the boat relative to an absolute Earth Coordinate system.
2. The position estimate shall be in Cartesian coordinates with an uncertainty of less than 10 cm RMS.
3. System provides continuously updated estimates of the boat heading relative to the same coordinate system used in R000-1 with an uncertainty less than 0.25 degree RMS.

**R001: Operational Swath**
1. Position estimates are accurate to values specified in R000-2 and R000-3 over a
   0 to 25 meter range.
2. Position estimates are accurate to values specified in R000-2 and R000-3 over
   a ± 90 degree in azimuth from the shore station.
3. Degraded accuracy shall be possible over a swath out to 200 meters in range.

**R002: System Control and Data Acquisition**

1. SCADA supports all the operating and maintenance modes.
2. SCADA serves as the Operational User Interface for both autonomous and
   manual control.
3. SCADA software is fully documented with source code, design, and end-user
   documentation.
4. SCADA UI shall allow a trained human technician to easily control and
   monitor the processes.
5. SCADA application software written in conformance with the LPARD-TDF-
   2012 API using the delivered SDK.
6. Following parameters are monitored and stored by SCADA:
   a. Boat position and orientation
   b. Raw LPARD position sensor data
   c. End-user hydrology sensor data
   d. Voltage, current, and power delivered by supplies
   e. Temperatures of all subsystems
   f. Operational State
7. Parameters mentioned in R002-6 have adjustable sampling rates of up to 60
   samples per minute and are recorded electronically with a time stamp.
8. Plots over a specified parameter range can be generated by the user.
9. SCADA logs commands, events, exceptions, faults, and operational state
   changes of the LPARD system.
10. SCADA has sufficient capacity for retaining data records over the lifetime of
    the system.
11. SCADA system is expandable to allow the incorporation of new boat position
    control algorithms and new sensors and expandability is possible without
    altering existing code.
12. Data storage is in a portable, non-proprietary format readily useable by
    common data analysis tools.
13. SCADA can automatically log an event, enable an alarm, and declare a fault
    to shutdown the system.
14. A loud aural signal shall be provided that SCADA uses for alarm conditions
    which the SCADA system is able to silence until a subsequent alarm condition
    occurs.
R003: Autonomous Mode and Manual Override
1. LPARD includes an autonomous closed loop controller that interfaces with the shore based RC control link for propulsion and maneuvering.
2. It is possible to switch back and forth between autonomous control and manual control with a minimal “glitch”.

R004: Control Modes
1. LPARD is capable of freeze, ferry, and script mode under autonomous control.
2. Freeze mode can hold constant position in river currents of less than 1 m/s with position error within 20 cm RMS.
3. Ferry mode allows the boat to translate in a straight line within 20 cm RMS to a current position to a designated second position.
4. Script mode allows LPARD to perform a sequence of movements consisting of freezes and ferries according to predefined script entered through the user interface.

R005: Data Link
1. SCADA contains a high-speed full duplex with bidirectional communication between the shore station and the boat.
2. The data link does not interfere with signals used for positioning.
3. Data link bit rate is established so to fulfill end user needs.

R006: User Interface
1. Real time display of relevant information is provided.
2. Both numeric and graphical representations are shown.
3. Simple interface for control modes and parameters is provided.

R007: Environmental
1. On-boat portion of system is designed and packaged so that it may be operated day or night, in moderate fog and rain, winds less than 20 km/h, and when splashed with clear or muddy water.
2. Equipment installed on the boat can survive immersion to IEC IP-67 standards and regain operation immediately after it surfaces.
3. Shore based equipment in the demonstration need only meet GPR002 and does not need to be water resistant, but the design shall be such that IP-67 standards can be met by the shore equipment in production.

R008: Payload
1. Equipment installed on the boat is minimized
2. Equipment on the boat is of a mass and location so as to not reduce the boat’s stability and resistance to capsizing.
3. Equipment leaves ample room and freeboard for the weight and size of typical end user payload.

**R009: API and SDK**
1. LPARD has a fully documented software API and SDK that allows an applications programmer to write software that uses interfaces and functions of SCADA system.
2. Software support for LPARD-TDF-2012 uses API to access SCADA functions.
3. SDK includes compilers, linkers, libraries, include files, utilities, as well as developer level documentation.
4. The complete SDK, including API documentation and application source under configuration control shall be delivered to or linked by the project web site.

**R010: Demonstration Application**
1. Demonstration application is user friendly.
2. Allows non-technical, minimally trained human user to witness an automatic demonstration.
3. Includes a large display.
4. Demonstration Application has few interactive options and a robust tolerance for possible operating user mistakes.
5. System damage is not possible via demonstration application.
6. This application software must be written in conformance with the LPARD API, built with tools provided in the SDK, and run on a suitable hardware platform included with and powered by the LPARD-TDF-2012 system.

**R011: Power Input Independence**
1. LPARD can operate temporarily without any power derived from AC mains.
2. All voltages needed are generated by LPARD-TDF-2012 circuitry and energy storage devices per GPR005.
3. LPARD can operate in a maintenance mode for long periods of time without draining batteries, where power is derived entirely from building mains.
4. It is easy to switch in and out of “maintenance power mode”.
General Project Requirements

GPR001: Documentation

1. Complete and accurate documentation must be provided with all projects. These documents shall include documents for mechanical and electrical fabrication, test results, software development kits, maintenance manual, user manual, and specification compliance matrices, and technical papers. All documentation shall be accumulated in electronic form, centralized in a project web site, and thoroughly indexed. The web site represents the primary point of delivery for document data items.

2. Text documents shall be written in a professional style commensurate with quality standards established by Lafayette College ECE writing courses (e.g. ES225 and ECE211).

3. All original paper documents should be scanned and stored electronically. The original should be disposed of per GPR012.

4. Test reports for hardware and software must show the date/time of testing, name and signature of the tester, and name/signature of any witnesses.

5. For all electronic PCB designs the following fabrication documents are required: dated, and numbered schematics or mechanical drawings on Lafayette College drawing format, circuit net-lists, bills of materials, artwork, assembly drawings, and all other files and instructions necessary for CAM or manual manufacturing. The source files for fabricating PCBs and editing linked schematics shall be clearly identified and preserved.

6. Documentation must be provided both for original designs and for any subcontracted designs. For purchased vendor components within the design, all vendor manuals and documentation shall be retained with the system. Proper mechanical drawings are required for fabricated mechanical parts. Manufacturers data sheets and interface drawings are required for all purchased components.

7. For software and firmware designs: Source code, and executable binaries for all applications; Verilog, constraints and configuration bitstreams for FPGAs; and ROM image files in commonly accepted JED or HEX formats for all PLDs.

8. A “Users” manual is required. This should be a high level document that explains all operational procedures and techniques needed to operate the system is a safe and effective manner, including “getting started”, “FAQ”, detailed explanations of all functions and controls, and user level calibration and maintenance.

9. A technical “Maintenance” manual is required. This should be a low level document that explains the unique technical principles and details of system operation. The maintenance manual includes information on any advanced
maintenance or calibration techniques that could be applied by an expert maintainer. A set of schematics, pinouts of all connectors, the signal assignments of all cables, and the semantics of all interfaces (hardware and software) must be documented within this manual.

10. All documentation must be provided and delivered in electronic form. Emailing a description of a document along with a URL into the project web site is an acceptable and desirable form of delivery. The use of standard and portable document formats (e.g. PDF, TXT), must be used so that the documentation can be viewed on any computer without the need for proprietary applications. The documentation must be arranged in an organized and professional manner on the project web site.

**GPR002: Environmental**

1. All projects must demonstrate reliable and normal functional operation in ambient lab temperatures of 15 °C to 30 °C, 10% to 80% RH, non-condensing. The overall system must tolerate a storage environment of 0 °C to +60 °C, 5% to 95% RH, non-condensing. Designs should use electronic components rated for commercial temperature range (0 –70 °C) or better.

**GPR003: EMI/EMC**

1. Unintentional electromagnetic radiation radiated or conducted from designs must meet US CFR Title 47Part 15 subpart B regulations for Class A digital equipment. Intentional radiators must meet subpart C regulations. Exemptions from 15.103 are not allowed.

**GPR004: Hazmats**

1. Hazardous materials should be avoided in designs. If use of a hazardous material is essential to the function of the design and there is no non-hazardous alternative, the use of the hazardous material must comply with the Lafayette College Chemical Hygiene Plan.
2. All materials used in electronic circuit fabrication must meet 2002/95/EC RoHS directives. NiCd or Lead-Acid batteries may not be used in new designs.
3. Any portion of the design or prototype that is discarded must be discarded according to the Lafayette College Chemical Hygiene plan. Also, projects should discard the collected electronic waste in an ecological-friendly manner as per the 2002/96/EC WEEE directive, either by ecological disposal or by reuse/refurbishment of the collected waste.

**GPR005: Safety and Good Practice**
1. All work shall comply with good industry practice that enhances reliability and maintainability. These practices include such items as:
   - Color coded wiring in accordance with applicable industry standard color codes (e.g., NFPA 79 or UL508 for power wiring, EIA/TIA 568 for network wiring, etc.)
   - Clear labeling of all controls and indicators.
   - An obvious and clearly labeled system-wide power shutdown switch.
   - Silkscreen on PCBs that includes reference designators, noted power supply voltages and other critical signals. Silkscreen must show a Lafayette College logo, the words “Made in USA”, a RoHS logo, assembly number and revision, and designated locations for serial numbers to be attached or written. PCB bottom copper should have text indicating the board part number and rev.
   - Fuses shall be socketed and at least 5 spares must be included with system delivery; breakers shall be resettable. All are readily accessible per maintainability requirements.
   - Service loops on all cable harnesses.
   - Access panels on enclosures.

3. Software/firmware developed must adhere to the principles and practice established in Lafayette College course CS205. Source code must be maintained under configuration control.

4. Embedded computer processors shall have reset buttons. These buttons must be readily acceptable for maintenance, but not so easy to hit that they degrade reliability.

5. Current drain analysis must be provided for all power supplies. Each supply voltage must have a current rating with a 50% safety factor over the anticipated peak current.

6. All resistors or other parts dissipating more than 25 milliwatts shall be identified and analysis shall be provided that shows all such parts are properly rated for peak and average power dissipation and have a proper heat sink and fan, if necessary, that provides adequate cooling over the ambient temperature range.

7. Components must be cooled such that the surface temperature is no greater than 40 70 degrees C above ambient.

8. Power dissipation rating of parts shall be 50% overrated over the required temperature range.

9. Working voltage of capacitors shall be 25% overrated above the peak voltage anticipated, including all expected glitches, spikes, and tolerance limits.

10. Project activities must adhere to the general Lafayette College safety policy, possibly augmented by any ECE Department or ECE Laboratory safety rules. Applicable rules are those in effect on the date of ATP.
11. Any project that develops AC RMS or DC potential differences greater than 30 Volts between any two points within the design (other than at the unmodified mains input side of a UL listed commercial power supply) must develop and implement an electrical safety plan before any circuits are powered. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants. The ECE Director of Laboratories must approve the electrical safety plan. A project team member must be designated project safety officer. It shall be the project safety officer’s responsibility to insure that all activities adhere to the project safety plan.

12. All equipment developed must comply with applicable national standards. Specifically, all electric supply, communications lines, and equipment must be designed, constructed, operated, and maintained in accordance to The National Electrical Safety Code (NESC) – ANSI C-2. Installations of electric conductors and equipment that connect to a building main supply of electricity must be designed, constructed, operated and maintained in accordance to The National Electric Code (NEC) ANSI/NFPA 70.

13. Any interconnection with the Lafayette College power grid is subject to the approval of Plant Operations. Any interconnection with the Lafayette College campus computer network is subject to the approval of the Information Technology Services department.

14. Use and design of lasers shall be in accordance with American National Standards Institute (ANSI) Z136.1-2000, "American National Standard for Safe Use of Lasers". Only low power Class I, II and Class IIIa (<5 mW) lasers should be used. If project requirements necessitate higher power, the project must develop and implement a laser safety plan before any laser work begins. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants.

15. All projects that involve RF power of any level must be designed to ensure that participants are not exposed to RF in excess of the recommended exposure limits adopted by the FCC (most recently in 1996, but note the proposed rule change in 2003). If project requirements necessitate radiated RF power in excess of 100 mW, the project must develop and implement an RF exposure safety plan before any high power RF work begins. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants.

16. Projects that contain recognized hazards must develop a project safety plan. Such hazards include but are not limited to high altitude, operation at sea, on lakes, or in rivers or mines, exposure to electrical, chemical, biological, radiological, or psychological hazards. All projects that involve machinery that create hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks, etc…, must develop and
implement a machinery safety plan before any machinery work begins. At a minimum the plan must address US Title 29 CFR Part 1910 Occupational Safety and Health Standards, Sub Part O, Machinery and Machine Guarding.

**GPR006: Reliability**

1. The system wide Mean Time Between Failures (MTBF) must be greater than 1000 hours over the system lifetime.
2. Reliability requirements must be demonstrated in the ATP both by analysis and by Inspection. The use of MIL-HDBK - 217, Bellcore TR - 332, or other equivalent techniques are encouraged for the analysis. Every part and subsystem in the full BOM must be explicitly considered in the MTBF analysis.
3. Parts with power dissipation over 25 milliwatts shall be identified and the reliability analysis shall include reliability derating of these components based on the expected dissipation.
4. In addition to the analysis, a reliability inspection shall be conducted during ATP where the system is shown to operate for 24 hours without any obvious failure.
5. Failures are defined as anything that causes system requirements to be missed. Failures include, but are not limited to computer software lock-ups, shutdowns caused by overheating, automatic operations stalled by exceptions or requests for human intervention, as well as random component failure.

**GPR007: Maintainability**

1. The system wide Mean Time To Repair (MTTR) must be less than 1 week over the system lifetime.
2. Maintainability requirements must be demonstrated in the ATP both by analysis and by Inspection. The use of MIL-HDBK - 472 (N1) and MIL-STD- 470B, ISO/ IEC 25000:2005, or other equivalent techniques are encouraged for the analysis.
3. In the maintainability analysis you should assume a stock of recommended spare parts. The list of these spare parts should be included in the ATP. The Users Manual should include a section giving simple troubleshooting procedures. The Maintenance Manual should have more elaborate diagnosis and troubleshooting resources.
4. In addition, a maintainability inspection shall be conducted during ATP where a novice using procedures included in the User Manual demonstrates the diagnosis and repair of a likely failure, and an expert using resources included
in the Maintenance Manual demonstrates the diagnosis and repair of an unlikely failure.

**GPR008: Manufacturability**

1. A production design is a project design that could reasonably be manufactured in large quantity (e.g. greater than 1000 units/yr). All production designs must be built from components and subassemblies that have a sustainable source of supply over the system lifetime. To demonstrate that this requirement is met, it must be shown that each item in the Bill of Materials (BOM) for the design is available from a minimum of two independent suppliers. In addition, industry trends shall be considered when selecting implementation options. Designs should choose options most aligned with future industry trends. The tolerances of components shall be considered in the design. Any component with a value that determines a critical voltage, time constant, frequency, or other parameter shall have a tolerance such that system requirements are met with 99% yield in manufacturing. An analysis shall be provided that identifies any tolerance critical components and proves that the tolerances are adequate to meet system requirements at that yield.

**GPR009: Life Cycle Sustainability**

N/A

**GPR010: Ethics**

1. As design engineers decide what can be done, always there is an implicit requirement for them to justify what ought to be done.

2. In acknowledgement of this implicit requirement, all ECE projects must be evaluated with respect to explicit ethical principles. An ethics report must be produced that analyzes social and political aspects of the design and justifies them with respect to such ethical principles. A summary of the ethics report is due at CDR.

3. The report must give ethical and/or political arguments for and against full development of your technology. Team members should divide into two, pick a pro or con side and each separately write that argument, then read the opposing side’s argument and write a rebuttal. Your arguments must be objective; that is to say, they must be based on reason and evidence. Arguments are not someone’s subjective opinion. Arguments must directly reference documented empirical evidence (e.g. research studies), generally recognized moral principles (e.g. utilitarianism), scientific or mathematical results (e.g. Game Theory), government enforced laws, or professional ethical codes (e.g. the IEEE Code of Ethics). Cite material in support of your arguments. Give a bibliography with citations.
4. The IEEE Code of Ethics must be explicitly considered in the ethical analysis.

**GPR011: Project Demonstration**

1. Completed projects must be demonstrated for review by ECE faculty.
2. It is highly encouraged that the entire design or some major functional subsystem of the design is suitable for continuous, unattended display as a self-contained, active demonstration that would excite the interest of students, faculty, and other ECE Department visitors. Such demonstrations must fit in a compact public area and operate safely and without unreasonable disturbance of its neighbors. User interaction with the demo is encouraged, but if activated by someone, the demonstration must deactivate automatically after some short delay. The MTTR and MTBF of the demonstration must meet or exceed the project-level Maintainability and Reliability requirements given herein. Visitor interaction with the demonstration, and possible failures caused by such interaction, shall be considered in the MTBF analysis.

**GPR012: Final Disposal of Projects**

1. Projects may be stored for future work, placed on display, or discarded. Time must be included in project schedules for final disposal.
2. If a project is to be stored, all its materials must be collected together in a single location. If possible, these materials should be enclosed in a sealed container, locked cabinet, or secure room that contains only these materials from one project and no other. If certain parts are impractical to store with the bulk of the project materials, these separate parts must be clearly labeled so their association with the stored project is obvious.
3. Projects placed on display may have portions not on display. The undisplayed portions shall be either stored or discarded as described herein.
4. Portions of projects or complete projects that are discarded must be discarded in accordance with Hazmat procedures described herein.
5. Test equipment moved from labs shall be replaced in its original location.
6. Trash, loose wires, scattered components, and other detritus resulting from frenzied development and testing shall be cleaned up.
7. Paper documents that have been scanned per GPR001 shall be placed in a paper recycling bin.
8. The project web site must be updated with all final documents. The documents on the final web site must match the delivered system. Obsolete documents on the web site shall be removed.
# Acceptance Test Report

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Due Date</th>
<th>Completed</th>
<th>Initials</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>D001: CDR Materials</td>
<td>3/5/2012 by 1 pm</td>
<td>FAIL</td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D002: Users Manual</td>
<td>Draft at CDR, final May 4</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D003: Final Report and Maintenance Manual</td>
<td>Draft at CDR, Final May 4</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D004: Acceptance Test Plan</td>
<td>Approved at CDR</td>
<td>LATE</td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D005: Acceptance Test Report</td>
<td>27 April</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D006: QA Audit Report</td>
<td>27 April</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D007: Project Web Site</td>
<td>Updated regularly</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D008: LPARD-TDF-2012 Integrated System</td>
<td>4 May</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D009: Conference Paper</td>
<td>6 April</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D010: Project Poster</td>
<td>4 May</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
<tr>
<td>D011: Detailed LPARD System Requirements</td>
<td>Draft at CDR, final 4 May</td>
<td></td>
<td>_______</td>
<td><em><strong>/</strong></em>/___</td>
</tr>
</tbody>
</table>
# Confirmation Matrix

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Proposed Modification</th>
<th>Confirmation Method</th>
<th>Pass/Fail</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>R000-1</td>
<td>None</td>
<td>Shown in Test 001 by noting the system updates while moving.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R000-2</td>
<td>10 cm RMS to 20 cm RMS. Analysis shown in document <em>Error Analysis</em></td>
<td>Shown in Test 001 by verifying the accuracy of position data.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R000-3</td>
<td>accurate within 1.5 degrees, with additional analysis to show how it can be improved</td>
<td>Shown in Test 001 by verifying the heading accuracy and by analysis in “HeadingAnalysis”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R001-1</td>
<td>None</td>
<td>Shown in Test 001 by examining accuracy at a range of distances.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R001-2</td>
<td>Proposed change to ±80 degrees with Omnidirectional Proposal due to azimuth limits of AZ/EL Positioner.</td>
<td>Shown in Test 001 by examining accuracy over a range of angles from the base station.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R001-3</td>
<td>Proposed change to define “degraded past 25 m” as within an absolute earth coordinate system defined by GPS positioning.</td>
<td>By analysis in Boat Position Tracking Independence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-1</td>
<td>Proposed change to only implement operation in maintenance mode</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-2</td>
<td>Proposed change to have manual control</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-3</td>
<td>None</td>
<td>Shown in “Coding Verification Documentation”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-4</td>
<td>None</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-5</td>
<td>None</td>
<td>Shown in “Coding Verification Documentation”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-6</td>
<td>None</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-7</td>
<td>None</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-8</td>
<td>None</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-9</td>
<td>None</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-10</td>
<td>None</td>
<td>By analysis in Lifetime Capacity Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-11</td>
<td>None</td>
<td>By analysis in Expandability Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-12</td>
<td>None</td>
<td>By analysis in Data Storage Format Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-13</td>
<td>None</td>
<td>Shown in Test 002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R002-14</td>
<td>Proposed change to writing specifications for the software and hardware that would be needed</td>
<td>By memo in Aural Signal Specification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R003-1</td>
<td>Waived by instructor</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R003-2</td>
<td>Proposed replacement with a specification</td>
<td>By analysis in “ManualControlAnalysis”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Turned on and off from an RC Controller rather than from the GUI for ease of use**
<table>
<thead>
<tr>
<th>R004-1</th>
<th>None</th>
<th>By inspection the code contains the ability to manipulate motors to handle the three modes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R004-2</td>
<td>Proposed replacement with showing that the SCADA supports the implementation of this feature</td>
<td>Shown in Test 002 by demonstration of necessary commands and data flow within the control loop</td>
</tr>
<tr>
<td>R004-3</td>
<td>Proposed replacement with showing that the SCADA supports the implementation of this feature</td>
<td>Shown in Test 002 by demonstration of necessary commands and data flow within the control loop</td>
</tr>
<tr>
<td>R004-4</td>
<td>None</td>
<td>Shown in Test 002</td>
</tr>
<tr>
<td>R005-1</td>
<td>None</td>
<td>Shown in Test 002 by showing real-time data transferred both ways.</td>
</tr>
<tr>
<td>R005-2</td>
<td>None</td>
<td>Shown in Test 001 by inspection of simultaneous operation of RF link and positioning.</td>
</tr>
<tr>
<td>R005-3</td>
<td>None</td>
<td>By memo detailing end user responses on necessary data speeds</td>
</tr>
<tr>
<td>R006-1</td>
<td>None</td>
<td>Shown in Test 002</td>
</tr>
<tr>
<td>R006-2</td>
<td>None</td>
<td>Shown in Test 002</td>
</tr>
<tr>
<td>R006-3</td>
<td>None</td>
<td>By inspection of the GUI</td>
</tr>
<tr>
<td>R007-1</td>
<td>Since we are not implementing the final boat packaging, we will spec a possible packaging design.</td>
<td>By analysis in “EnvironmentalAnalysis”</td>
</tr>
<tr>
<td>R007-2</td>
<td>See proposed change in R007-1.</td>
<td>By analysis in “EnvironmentalAnalysis”</td>
</tr>
<tr>
<td>R007-3</td>
<td>None</td>
<td>By analysis in “EnvironmentalAnalysis”</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>R008-1</td>
<td>None</td>
<td>By analysis in Boat Payload Analysis by explaining the necessity of all hardware on boat</td>
</tr>
<tr>
<td>R008-2</td>
<td>None</td>
<td>By analysis in Boat Payload Analysis by examining the weight budget and providing an example placement diagram</td>
</tr>
<tr>
<td>R008-3</td>
<td>None</td>
<td>By analysis in Boat Payload Analysis by comparing to an example payload</td>
</tr>
<tr>
<td>R009-1</td>
<td>None</td>
<td>Shown in “API Documentation”</td>
</tr>
<tr>
<td>R009-2</td>
<td>None</td>
<td>Code will be inspected by team member and verified according to “API Documentation”</td>
</tr>
<tr>
<td>R009-3</td>
<td>None</td>
<td>Shown in “API Documentation”</td>
</tr>
<tr>
<td>R009-4</td>
<td>None</td>
<td>By inspection on project website.</td>
</tr>
<tr>
<td>R010-1</td>
<td>None</td>
<td>Shown by Demo App Inspection.</td>
</tr>
<tr>
<td>R010-2</td>
<td>None</td>
<td>Shown by Demo App Inspection.</td>
</tr>
<tr>
<td>R010-3</td>
<td>None</td>
<td>By inspection, demo will use a full computer screen.</td>
</tr>
<tr>
<td>R010-4</td>
<td>None</td>
<td>Shown by Demo App Inspection.</td>
</tr>
<tr>
<td>R010-5</td>
<td>None</td>
<td>By analysis in Demonstration Application Specification</td>
</tr>
<tr>
<td>R010-6</td>
<td>None</td>
<td>By inspection of code and demo hardware.</td>
</tr>
<tr>
<td>R011-1</td>
<td>Proposed replacement with analysis, though AC “Maintenance Power Mode” will still be</td>
<td>By analysis in “PowerAnalysis”</td>
</tr>
<tr>
<td>GPR001</td>
<td>None</td>
<td>By inspection on project website.</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>GPR002</td>
<td>None</td>
<td>By analysis in “Environmental Analysis”</td>
</tr>
<tr>
<td>GPR003</td>
<td>None</td>
<td>By analysis in “EMI/EMC Analysis”</td>
</tr>
<tr>
<td>GPR004</td>
<td>None</td>
<td>By analysis in “HAZMATS Analysis”.</td>
</tr>
<tr>
<td>GPR005</td>
<td>None</td>
<td>By analysis in “Safety and Good Practice Analysis”</td>
</tr>
<tr>
<td>GPR006</td>
<td>None.</td>
<td>By analysis in “Reliability Analysis”</td>
</tr>
<tr>
<td>GPR007</td>
<td>None.</td>
<td>Inspection shows usefulness of Maintenance Manual and User’s Manual, also by analysis in “Maintainability Analysis”</td>
</tr>
<tr>
<td>GPR008</td>
<td>None.</td>
<td>By analysis in “Manufacturability Analysis”</td>
</tr>
<tr>
<td>GPR010</td>
<td>None.</td>
<td>Shown in video posted to project website at: <a href="http://sites.lafayette.edu/ece492-sp12/cdr-materials/ethics-report/">http://sites.lafayette.edu/ece492-sp12/cdr-materials/ethics-report/</a> PASS</td>
</tr>
<tr>
<td>GPR011</td>
<td>None.</td>
<td>Demonstration will take place after the final report for ECE Faculty</td>
</tr>
<tr>
<td>GPR012</td>
<td>None.</td>
<td>By inspection of Labs and project display</td>
</tr>
</tbody>
</table>


ATR Appendix

T001: Range Measurements

Criteria for Success: For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS range error with a 90% confidence interval. If this value is below 14 cm, then the test is successful.

Sample standard deviation: \( \sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{10 - 1} \), where \( x_i \) is the \( i^{th} \) measured range and \( \bar{x} \) is the expected distance, and \( n \) is the number of samples taken

\[ C = \chi^2_{(n)} (.90) = 4.865 \]

Confidence Interval @ 90% for \( \sigma_s^2 \):

\[
\left[ 0, \frac{(n - 1)\sigma_s^2}{4.865} \right]
\]

\( Eq1: \) \( x_{RMS\text{Confidence}} = \sqrt{\bar{x}^2 + \sigma^2} \)

5m points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

10m points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

15m points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

20m points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

\( X_{rms} \) computed by Eq1: __________

25m points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____
**T001: Azimuth Measurements**

**Criteria for Success:** For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS azimuth angle with a 90% confidence interval. If this angle is less than 1 degree off from the expected value, then the test is successful.

Sample standard deviation: \( \sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{10 - 1} \), where \( x_i \) is the \( i \)th measured angle and \( \bar{x} \) is the expected angle, and \( n \) is the number of samples taken.

\[
C = \chi^2_{(n)}(.90) = 4.865
\]

Confidence Interval @ 90% for \( \sigma^2 \):

\[
\left[ 0, \frac{(n - 1)\sigma_s^2}{4.865} \right]
\]

**Eq1:** \( x_{\text{RMSConfidence}} = \sqrt{\bar{x}^2 + \sigma^2} \)

**3.81 degrees at 15':**
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

\( X_{rms} \) computed by Eq1: ______

**11.31 degrees at 15':**
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

\( X_{rms} \) computed by Eq1: ______

**19.29 degrees at 15':**
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

\( X_{rms} \) computed by Eq1: ______
-3.81 degrees at 15’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

-11.31 degrees at 15’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

-19.29 degrees at 15’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

9.46 degrees at 60’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

19.71 degrees at 60’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

-9.46 degrees at 60’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

-19.71 degrees at 60’:
10 points: ____, ____, ____, ____, ____, ____, ____, ____, ____, ____

Xrms computed by Eq1: __________

Pass: ___________ Fail: ___________

T001: Elevation Measurements

Criteria for Success: For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown above, which represents the RMS elevation angle with a 90% confidence interval. If this value is off from the expected angle by less than 1 degree, then the test is successful.
11.31 degrees:
10 points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

-45 degrees:
10 points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

69.68 degrees:
10 points: ____, _____, _____, _____, _____, _____, _____, _____, _____, _____

Xrms computed by Eq1: __________

Pass: __________ Fail: __________

T002: R002-1

Criteria for Success: SCADA supports the following modes: sensor calibration, acquisition, tracking, changes in control mode, default mode with loss of data link; while logging of all data.

Sensor Calibration  Pass: __________  Fail: __________
Acquisition  Pass: __________  Fail: __________
Tracking  Pass: __________  Fail: __________
Change to Ferry  Pass: __________  Fail: __________
Change to Freeze  Pass: __________  Fail: __________
Enter Default  Pass: __________  Fail: __________

T002: R002-2

Criteria for Success: Success will be determined if the mode can be changed and then verified through simulation of the boat. All of the mode changes run should be logged in the laptop software’s system log and can be verified by checking its respective CSV file.

Pass: __________  Fail: __________
**T002: R002-4**

*Criteria for Success:* Will be verified by end user input in the form of feedback to evaluate our final user that caters to ease of use.

*Pass:* __________  *Fail:* __________

**T002: R002-6**

*Criteria for Success:* If a separate CSV file with session data has been created for: each sensor, initial position fusion from polar to Cartesian, and completely fused position displayed in the GUI. This can be verified by a non-existent directory before session use, as well as an affirmation of after session use by means of checking each file is present and that it contains correct data other than header information.

*Pass:* __________  *Fail:* __________

**T002: R002-8**

*Criteria for Success:* Success will be determined by demonstrating an ability to use Microsoft Excel to generate a plot of two arbitrary sensor CSV log files that are stored in the session directory.

*Pass:* __________  *Fail:* __________

**T002: R002-9**

*Criteria for Success:* Success will be determined if the system log has been generated for the test session. The program will log all data displayed in the GUI under system output which will contain all the parameters listed above. All system events displayed should be recorded by hand and compared with the logged information to verify a correct log file. Additional information may be logged and should not preclude success of this requirement being demonstrated.

*Pass:* __________  *Fail:* __________

**T002: R002-13**

*Criteria for Success:* Success will be determined if the fault (lost connection to boat by turning off its micro-controller) tested is affirmed in the system log and displayed on the GUI.

*Pass:* __________  *Fail:* __________
**T002: R003-1**

*Criteria for Success:* Instructor signs off on requirement being waived.

Pass: ___________  Fail: ___________

**T002: R004-2**

*Criteria for Success:* Success will be determined by the successful system logging of freeze mode and simulation holding boat position.

Pass: ___________  Fail: ___________

**T002: R004-3**

*Criteria for Success:* Success will be determined by the successful system logging of ferry mode (with its designated inputs) and simulation reaching those inputs.

Pass: ___________  Fail: ___________

**T002: R004-4**

*Criteria for Success:* Success will be determined by the successful system logging of the script that is run and simulation reaching those inputs.

Pass: ___________  Fail: ___________

**T002: R005-1**

*Criteria for Success:* During step 18, real time data appeared on the GUI and the Terminal display.

Pass: ___________  Fail: ___________

**T002: R006-1**

*Criteria for Success:* Success will be determined if the GUI implements R006-2 at the rate of data recording, which by default will be once per second.

Pass: ___________  Fail: ___________

**T002: R006-2**
Criteria for Success: Success will be determined by the presence of a graphical situational representation in the GUI. In addition, GUI will also have a field allocated for position, sensors on the boat, and a field for payload sensors. Each will contain numerical representations of any sensor listed.

Pass: __________  Fail: __________

T003: R000-1
Criteria for Success: The value of (x,y) position of the boat displayed by the GUI changes as the boat is moved from one position to another (assuming that the mover does not block the sensors).

Pass: __________  Fail: __________

T003: R000-2
Criteria for Success: For each location, take 10 samples from the CSV file and calculate the result of Eq1 as shown below, which represents the RMS x,y position with a 90% confidence interval. If the x and the y value resulting from this equation for each location is has less than 20cm error, then the test is successful.

Sample standard deviation: $$\sigma_s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{10-1}$$, where $x_i$ is the $i^{th}$ measured position and $\bar{x}$ is the expected position, and $n$ is the number of samples taken.

$$C = \chi^2 (n) (.90) = 4.865$$

Confidence Interval @ 90% for $\sigma^2$:

$$\left[ 0, \frac{(n-1)\sigma_s^2}{4.865} \right]$$

$$\text{Eq1: } x_{\text{RMS Confidence}} = \sqrt{\bar{x}^2 + \sigma^2}$$

Pass: __________  Fail: __________

T003: R000-3
Criteria for Success: For each angle, take 10 samples from the CSV file and calculate the result of Eq1 as shown above, which represents the RMS angle with a 90%
confidence interval. If the angle error resulting from this equation for each location is below the proposed 1.5 degrees, then the test is successful.

90°:
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

$X_{rms}$ computed by Eq1: _________

45°:
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

$X_{rms}$ computed by Eq1: _________

0°:
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

$X_{rms}$ computed by Eq1: _________

-45°:
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

$X_{rms}$ computed by Eq1: _________

-90°:
10 points: ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____ , ____

$X_{rms}$ computed by Eq1: _________

Pass: __________  Fail: __________

T003: R001-1

Criteria for Success: If the positions measured in R000-2 are within the proposed 20 cm value (analysis given in the document Error Analysis), and both the IR and ultrasound sensors have proven 25 meter range via Test001.

Pass: __________  Fail: __________
**T003: R001-2**  
*Criteria for Success:* Points P1 and P5 labeled in Figure 1 (if placed at the labeled positions), shows a $\sim \pm 83$ degree operational swath. If points P1 and P5 are measured successfully in R000-2, then these points therefore meet the operational swath requirements.

Pass: ___________  Fail: ___________

**T003: R001-3**  
*Criteria for Success:* As long as the GPS is sending data to the GUI program over the laptop via the RF link, we will have “degraded accuracy” by means on the GPS position. The requirement is therefore successful if the GUI program on the laptop displays the GPS value and the provided analysis (shown in document RF Distance Analysis) shows that our RF link is capable of communicating over 200 meters (200m QA test for RF is impractical).

Pass: ___________  Fail: ___________

**T003: R005-2**  
*Criteria for Success:* Success criteria for R000-2 and R000-3 have been met - as there is position data being transmitted to the boat (shore sensors) and to the shore (fused position), meeting those requirements implies the data link does not interfere.

Pass: ___________  Fail: ___________

ATR Accepted - Signature: _____________________  Date: __/__/__

Signature: _____________________  Date: __/__/__

Signature: _____________________  Date: __/__/__