**USDOT GlidePath Project**

**System Acceptance Test Report**

**Version 2.1 November 10, 2015**

LEIDOS

Security Classification: Unclassified

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# 1.0 Test Results Summary Report

|  |  |  |  |
| --- | --- | --- | --- |
| **Agenda #** | **Test Case ID** | **Test Case Name** | **Result** |
|  | **Security** | | |
| 1 | TO17\_SEC\_01 | Prototype Security |  |
| 4 | TO17\_SEC\_02 | PC Password Protection |  |
|  | **Infrastructure** | | |
| 6 | TO17\_INF\_01 | Infrastructure Readiness |  |
|  | **Vehicle** | | |
| 2 | TO17\_VEH\_01 | Documentation of Vehicle Functionality |  |
| 3 | TO17\_VEH\_02 | In-Vehicle Equipment |  |
| 5 | TO17\_VEH\_03 | Basic Longitudinal Control |  |
| 7 | TO17\_VEH\_04 | Vehicle Behavior |  |
|  | **Algorithm** | | |
| 8 | TO17\_ALG\_01 | Demonstration of Algorithm Functionality |  |
| 10 | TO17\_ALG\_02 | Demonstration of Algorithm Process |  |
|  | **Data** | | |
| 11 | TO17\_DATA\_01 | Output Data Post-Processing |  |
|  | **Driver-Vehicle Interface** | | |
| 9 | TO17\_DVI\_01 | Driver-Vehicle Interface |  |

# 2.0 Test Cases

The following tables include the specific procedures that will verify the functionality of the prototype in accordance with the technical requirements. As each procedure is implemented, the test results (outcome, pass/fail) will be noted to the right and will be accompanied by the FHWA General Task Manager’s initials where each technical requirement is verified.

**Advisory: The test procedures included below are written for Authorized Users who have training in the GlidePath Operating Procedures. Please review the GlidePath Vehicle Basic Manual and read through the full test case procedures before commencement of each test to ensure all safety protocols are followed.**

For test cases that denote required Data Outputs, relevant documentation will be attached to the signed copy of the test report and stored on file for reference.

## 2.1 Security

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_SEC\_01** |
| **Test Case** | **Prototype Security** |
| **Reference** |  |
| **Objective** | To document the agreement to comply with the requirements listed below,  including physical and operational security. |
| **Requirements verified** | • *TO17\_SEC\_01v1* – Physical Security  • *TO17\_SEC\_02v1* – Operational Security |
| **Brief**  **Description** | The team will provide signed agreements to abide by and enforce the listed security protocols. |
| **Data Outputs** | Signed agreements will be provided to the FHWA General Task Manager and  saved on file. |

**The signature below attests to receipt of signed Security Protocol Agreements from the**

**GlidePath staff:**

FHWA GTM Signature Date GlidePath Project Lead Date

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_SEC\_02** |
| **Test Case** | **PC Password Protection** |
| **Reference** |  |
| **Objective** | Verification of the restrictions implemented for system access to the in-vehicle  processors. |
| **Requirements verified** | • *TO17\_SEC\_03v1* – System Access |
| **Brief**  **Description** | The team will log into the in-vehicle PCs using the documented user name and  password which will be shared with the FHWA General Task Manager and included in the Prototype Operation and Maintenance document. |
| **Data Outputs** | none |

***EVALUATION PROCEDURES***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Step** | **Instruction** | **Expected**  **Outcome / Requirement**  **Verified** | **Actual**  **Result / Pass or**  **Fail** | **Initial** |
| **1** | With the vehicle parked in the garage, plug into the workstation  monitor. |  |  |  |
| **2** | Turn on the workstation monitor and type in the username and  password (to be provided by test conductor) | ***TO17\_SEC\_***  ***03v1* – System**  **Access** |  |  |

**The signature below indicates acceptance of the Prototype as compliant with the requirements listed in this test case:**

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## 2.2 Infrastructure

The infrastructure requirements will be verified by visual inspection and demonstration prior to any field testing. The Intelligent Intersection at TFHRC will be configured to support the application using a fixed

time signal cycle that is broadcast over DSRC.

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_INF\_01** |
| **Test Case** | **Infrastructure Readiness** |
| **Reference** |  |
| **Objective** | Verification of the fixed-time signal cycle and the accurate broadcast of SPaT,  MAP, and WSAs over DSRC. |
| **References** | • |
| **Requirements verified** | • *TO17\_FUN\_17v1* – Signal Control  • *TO17\_FUN\_18v1* – DSRC Communication (Infrastructure) |
| **Brief**  **Description** | Using the appropriate tools and methods, the test conductor will verify that the  signal cycle of the intersection is set to fixed-time and will not be actuated by any of the local loop detectors. Additionally, the test conductor will verify that SPaT,  MAP, and WSAs are being broadcast over the air using DSRC. |
| **Entrance**  **Criteria** | • Vehicle is equipped with a DSRC Protocol Analyzer |
| **Configuration** | • Traffic controller is set to normal function (not flash)  • SPaT Black Box is connected to traffic controller over Ethernet and pointed to the test RSU |
| **Exit Criteria** | • Loop detectors are not active  • Traffic signal operates with constant, fixed time cycle  • SPaT, MAP, and WSAs are captured from the vehicle |
| **Data Outputs** | Saved capture from DSRC Protocol Analyzer and documentation of observed  signal timing for at least three cycles. |

***EVALUATION PROCEDURES***

The following instructions will guide the relevant test staff through the necessary protocols to verify that the traffic signal operates with fixed timing

|  |  |  |  |
| --- | --- | --- | --- |
| **Step Instruction Expected Actual Initial**  **Outcome / Result / Requirement Pass or Verified Fail** | | | |
| **1** At the Intelligent Intersection’s traffic controller cabinet, verify that all loop detectors are turned off and that the controller is set  to fixed time operation in accordance with the timing protocol  listed below. | | | |
| **2 Data Recorder** shall compose a record of the observed signal timing from the Econolite Traffic Signal Controller | **TO17\_FUN\_** | |  |
| **17v1** |  | |
|  | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Step Instruction Expected Actual Initial**  **Outcome / Result / Requirement Pass or Verified Fail** | | | | | |
| **3** | **Lead Passenger** shall run DSRC Protocol Analyzer to identify  relevant message sets and save a capture file with the following name:  YearMonthDay\_TOINF01\_Pass/Fail\_UTCTim e.pcap  where “YearMonthDay” and “UTCTime” reflect the capture start time. | SPaT, MAP,  and WSAs are observed  **MSG/PSID**  SPAT/BFE0  MAP/BFF0  WSA/35 | | | |
| **4 Post Processing** Saved .pcap files should be analyzed to verify the frequency of the broadcasts meet the requirements | | | **TO17\_FUN\_** | |  |
| **18v1** |  | |
|  | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Expected Phase**  **Length** | | | **Actual Phase**  **Length** | | |
| **Phase** | **G** | **Y** | **R** | **G** | **Y** | **R** |
| 2/6 (NB/SB) | 27 | 3 | 30 |  |  |  |
| 4/8 (EB/WB) | 27 | 3 | 20 |  |  |  |

**The signature below indicates acceptance of the Prototype as compliant with the requirements listed in this test case:**

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## 2.3 Vehicle

The vehicle related requirements require multiple test cases be run to verify the component functionalities of the prototype that will ultimately build to the full application. Many of these test cases reference the

“XGV Start Up Procedures” in their Entrance Criteria; these procedures are documented as part of the

XGV training materials and a quick-start guide will be mounted on the passenger side of the vehicle.

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_VEH\_01** |
| **Test Case** | **Documentation of Vehicle Functionality** |
| **Reference** |  |
| **Objective** | Verify documentation of vehicle settings and configurations that will not be field  tested, such as automated lateral control and the maximum acceleration thresholds. |
| **Requirements verified** | • *TO17\_FUN\_09v1* – Acceleration Control Commands  • *TO17\_FUN\_10v1* – Deceleration Control Commands  • *TO17\_INT\_02v1* – Standard Command Structure |
| **Brief**  **Description** | Review of documentation that prototype vehicle has the capability for automated  lateral control and the maximum speed and acceleration thresholds for automated longitudinal control of the vehicle. Verification that vehicle utilizes JAUS via  Ethernet as the command structure for control commands to the vehicle. |
| **Configuration** |  |
| **Data Outputs** | User manual for XGV |

***RELEVANT DOCUMENTATION***

The following requirements have been included for quick reference and are supported by documentation from the *TORC ByWire XGV User Manual Hybrid Escape Drive-by-Wire Platform, version 1.5.*

• *TO17\_FUN\_09v1* – Acceleration Control Commands The prototype SHALL have internal ‘closed-loop control’ to accelerate to a target speed by commanding the target speed and acceleration.

o The TORC ByWire XGV is equipped with closed loop drive-by-wire control that allows a user to command a desired acceleration and speed. This functionality is described in **Section**

**5.1 “Control Schema Overview”** on page 8 of the User Manual.

• *TO17\_FUN\_10v1* – Deceleration Control Commands The prototype SHALL have internal ‘closed-loop control’ to decelerate to a target speed by commanding the target speed and deceleration, within the capabilities of the vehicle.

o The TORC ByWire XGV is equipped with closed loop drive-by-wire control that allows a user to command a desired acceleration and speed. This functionality is described in **Section**

**5.1 “Control Schema Overview”** on page 8 of the User Manual.

• *TO17\_INT\_02v1* – Standard Command Structure

The prototype SHALL utilize JAUS via Ethernet (SAE/TP 2009-01-3250) as the command structure to enable control commands to be sent to control the vehicle.

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| **Test Case #** | **TO17\_VEH\_02** |
| **Test Case** | **In-Vehicle Equipment** |
| **Reference** |  |
| **Objective** | Visually inspect DSRC Communication, Positioning, and Processing components  installed in the vehicle, as well as Ethernet cable connections. Component functionality is documented in component user manuals which will be available for reference. |
| **Requirements verified** | • *TO17\_FUN\_14v1* – DSRC Communication  • *TO17\_FUN\_15v1* – Positioning  • *TO17\_FUN\_19v1* – In-Vehicle Processing  • *TO17\_INT\_01v1 –* Ethernet Interface |
| **Brief**  **Description** | The project team will provide an in-person overview of the vehicle components and interfaces as compliant with the requirements listed above. |
| **Configuration** |  |
| **Data Outputs** |  |

***RELEVANT DOCUMENTATION***

This test case will be completed by visual inspection of the in-vehicle equipment components, including the DSRC After-market Safety Device (ASD), Positioning System, In-Vehicle Processing capability, and Ethernet interface, as pictured below, as well as the CANBus interface, which is not visible in this photo.



Positioning System DSRC Communication

Ethernet Interface

In-Vehicle

Processing

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| **Test Case #** | **TO17\_VEH\_03** |
| **Test Case** | **Basic Longitudinal Control** |
| **Reference** |  |
| **Objective** | Verify capability of the vehicle to receive and implement electronic speed  commands in the forward and reverse direction. |
| **Requirements verified** | • *TO17\_FUN\_01v1 –* Automated Longitudinal Control  • *TO17\_FUN\_02v1* – Directional Control  • *TO17\_FUN\_03v1* – Automated Lateral Control  • *TO17\_FUN\_04v1* – Decoupled Longitudinal and Lateral Control |
| **Brief**  **Description** | Using the TORC-furnished XGV Operator Control Unit (OCU) application, the  test conductor will demonstrate the basic capabilities of the vehicle to operate under automated longitudinal control in compliance with the requirements. |
| **Configuration** | In accordance with the XGV Start Up Procedures, the vehicle must be in the  Automated state for this test |
| **Data Outputs** | Saved capture from DSRC Protocol Analyzer and documentation of observed  signal timing for at least three cycles. |

***EVALUATION PROCEDURES***

|  |
| --- |
| **Step Instruction Expected Outcome / Actual Result / Initial**  **Requirement Verified Pass or Fail** |
| **1** Start-up the vehicle in  “Manual” mode and pull  out of the garage, and set the car to “Automated” mode and enable Manual Steering through the dashboard display. |
| **2** Connect PC to Ford network switch via  Ethernet, configure static  IP with 192.168.0.XX |
| **3** Plug the X-Box  controller from the center  console into the PC’s  USB port |
| **4** Start Up TORC ByWire  XGV OCU Software |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step Instruction Expected Outcome / Actual Result / Initial**  **Requirement Verified Pass or Fail** | | | | | | | | | |
| **5** Verify communication is Red “Communications established with XGV Time Out” error will  be present if communication is not established | | | | | | | | | |
| **6** Select “Request MPD” Control | | | | | | | | | |
| **7** Click on Motion Profile  Driver Tab, and use X-  Box Controller to move the vehicle. The right toggle is used for longitudinal control; press the toggle forward  to accelerate forward and pull the toggle back to accelerate in reverse. |  | *TO17\_FUN\_01v1* | | | | |  |  |  |
| *–* Automated  Longitudinal | |  | | | |
| Control |  | | | | |
|  | | | | | |
| *TO17\_FUN\_02v1* | | | | |  |
| – Directional | |  | | | |
| Control |  | | | | |
|  | | | | | |
|  | | | | | | | |
| **8** Using the dashboard controller, enable  automated steering and disengage automated speed control. | | | | | | | | | |
| **9** While the driver controls the gas and brake pedals, have the passenger use  the X-Box Controller’s left toggle to move forward and backward for steering control. | | *TO17\_FUN\_03v1* | | | | |  |  | |
| – Automated | |  | | | |
| Lateral Control | | |  | | |
|  | | | | | |
| *TO17\_FUN\_04v1* | | | | |  |
| – Decoupled | |  | | | |
| Longitudinal and | | | |  | |
| Lateral Control | | |  | | |
|  | | | | | |

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| **Test Case #** | **TO17\_VEH\_04** |
| **Test Case** | **Vehicle Behavior** |
| **Reference** |  |
| **Objective** | Verify that the vehicle behavior is compliant with the requirements listed below  and activated using the required control mechanisms. |
| **Requirements verified** | • *TO17\_FUN\_05v1 –* Automated Control Switch  • *TO17\_FUN\_06v1* – Manual Override  • *TO17\_FUN\_07v1* – Additional Control Mechanism  • *TO17\_BEH\_01v1* – Ignition Off to Park  • *TO17\_BEH\_02v1* – Park to Manual  • *TO17\_BEH\_03v1* – Park to Automated  • *TO17\_BEH\_04v1* – Automated to Manual  • *TO17\_BEH\_05v1 –* Manual to Automated  • *TO17\_BEH\_06v1* – Automated to EcoDrive  • *TO17\_BEH\_07v1* – EcoDrive to Automated  • *TO17\_BEH\_08v1* – EcoDrive to Idle  • *TO17\_BEH\_09v1* – Idle to Automated  • *TO17\_BEH\_10v1* – Idle to Manual |
| **Brief**  **Description** | The test conductor will demonstrate the transition between each state listed in the  requirements to verify that the vehicle behaves as expected, especially as dictated by the required physical control mechanisms (activation key, brake pedal, emergency override button). |
| **Entrance**  **Criteria** | The vehicle must be: 1  - Disconnected from shore power ; and,  - Parked outside at TFHRC.  The Test Driver must be seated in the driver’s seat. The Driver and all Passengers must have their safety belts fastened.  Traffic control staff must be deployed and ready to monitor and manage traffic for  the test runs. |
| **Configuration** | - Activation Key must be turned to “0”; |
| **Data Outputs** |  |

1 For more information about these settings, please review the *GlidePath Vehicle Basic Manual.*

***EVALUATION PROCEDURES***

The following procedures are designed to demonstrate how the vehicle transitions between different states. For quick reference, the State Diagram is included below the procedures table.

**ADVISORY: Before engaging automated control of the vehicle, the driver must enable “Manual Steering” through the XGV Radio**

**Interface. Please see the “XGV Start-Up Procedures” for more information.**

|  |  |  |
| --- | --- | --- |
| **Step Instruction Expected Outcome / Requirement Actual Result /**  **Verified Pass or Fail** | | |
| **1** Turn the ignition key to start the vehicle. Driver dash will display “Ready to  Drive.” | | |
| **2** With the vehicle running and the gear shift in P, turn XGV will turn on and engage the the activation key from “0” to “1.” brake.  **TO17\_BEH\_01v1 – Ignition Off to**  **Park**  **TO17\_FUN\_05v1 – Automated**  **Control Switch** | | |
| **3** In the center console, override the TORC link to the Pause and Stop lights on the XGV  handheld SafeStop controller, by pressing the Bypass SafeStop controller will turn green, the  button three times, waiting in between for the blue Link light will remain red, and the light to blink. brake will release. | | |
| **4** Move the gear shift from “P” to “D” and drive the | **TO17\_BEH\_02v1 – Park to Manual** |  |
| vehicle in manual mode to the Experimental Start  Location. | | |

|  |
| --- |
| **Step Instruction Expected Outcome / Requirement Actual Result /**  **Verified Pass or Fail** |
| **5** With your foot on the brake, move the gear shift from  “D” to “N,” depress the Yellow Emergency Manual  Override button. |
| **6** Release the brake and Yellow Emergency Manual The XGV will activate and engage the  Override button. brake.  **TO17\_BEH\_05v1 – Manual to**  **Automated** |
| Caution: Before engaging automated control, use the XGV Radio Interface to enable “Manual Steering.” For additional  information, please reference the XGV Start-Up Procedures document and the XGV User Manual. |
| **7** Turn on the tablet display using the power button, Screen will display a black and red swipe right to unlock the screen and select the menu screen.  “GlidePath” App Icon. |
| **8** Click “START Glidepath” and then select “OK.” Screen will display a pop-up that reads  “Done starting Glidepath!” that will  disappear upon clicking “OK.” |
| **9** Click “Navigate to Glidepath DVI.” Screen will display the System  Advisory. |
| **10** Read the System Advisory and select “OK” to Screen will display Driver Input screen proceed with the test case. with operational speed selection and  current signal phase and timing information. |
| **11** Select “20” for the Operational Speed using the down arrow. |
| **12** Verify that all elements of Activation Sequence are  Green and that Signal Status is actively counting  SPaT |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step Instruction Expected Outcome / Requirement Actual Result /**  **Verified Pass or Fail** | | | | | | | | | | |
| **13** To start automated speed control, wait for the SPaT to The vehicle siren will sound and the read **0 seconds of Red** time and prepare to assume light will flash as the GlidePath  manual steering and select “Go.” application engages automated speed control and accelerates forward.  **TO17\_BEH\_06v1 – Automated to**  **EcoDrive** | | | | | | | | | | |
| **14** When there are 5 seconds of red remaining, a “GO” button will flash green on the screen. Visually inspect the intersection and surrounding area for safety  conflicts and press “GO” on the DVI display when ready to proceed.  NOTE: The application will not resume until BOTH  the light turns green and the driver has selected GO. |  | The vehicle will come to a complete  stop at the red light and EcoDrive will halt until the driver re-engages the DVI. | | | | | | |  |  |
| **TO17\_BEH\_07v1 – EcoDrive to** | | | |  | | |
| **Automated** |  | | | | | |
|  | | | | | | |
|  | | | | | | | | |
| **15** After the vehicle passes through the intersection and | | **TO17\_BEH\_08v1 – EcoDrive to Idle** | | | | | |  | | |
| approaches the Experimental End Location, the  application will automatically turn off EcoDrive and prompt the driver to resume Manual control. | | | | | | | | | | |
| **16** When the DVI displays the following message: “Experiment ended; driver resume manual control,”  tap the brake, shift to D and resume manual control of the vehicle. | | When the brake is depressed,  automated control will disengage and the vehicle will be in the “IDLE” state. When the gear shift moves from “N” to “D” the vehicle will return to the “MANUAL” state. | | | | | | |  | |
| **TO17\_FUN\_07v1 – Additional** | | |  | | | |
| **Control Mechanism** | |  | | | | |
|  | | | | | | |
| **TO17\_BEH\_10v1 – Idle to Manual** | | | | |  | |

**Step Instruction Expected Outcome / Requirement**

**Verified**

**Actual Result / Pass or Fail**

**17** At the end of the experimental run, turn the vehicle around and return to the Experimental Start Location.

**The following steps demonstrate the functionality of additional control mechanisms, including the emergency override button, gear shift, and brake pedal.**

**18** Move the gearshift to P to park the vehicle.

**19** Release the brake pedal, reset the yellow emergency override button and move the gearshift to N.

**TO17\_BEH\_03v1 – Park to**

**Automated**

**20** Move the gearshift to D and assume manual control of the vehicle to move forward and backward.

**TO17\_BEH\_04v1 – Automated to**

**Manual**

**21** Move the gearshift back to N, release the brake and reset the yellow emergency button

**22** Engage the application using the DVI, and press

“GO” when ready.

**23** As the vehicle begins to accelerate, tap the brake to manually override the application and transition to the “Idle” state.

**24** Release the brake, and press and release the yellow emergency override button to return to the “Automated” state and re-engage the application through the DVI.

**TO17\_FUN\_06v1 – Manual Override**

**TO17\_BEH\_09v1 – Idle to**

**Automated**



**The signature below indicates acceptance of the Prototype as compliant with the each of the requirements listed in this test case and behaves in accordance with the state diagram depicted above:**

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## 2.4 Algorithm

The primary functionality of the algorithm will be verified through both a high-level, and ‘behind-the- scenes’ demonstration, as well as a post-processing analysis of the output data.

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_ALG\_01** |
| **Test Case** | **Demonstration of Algorithm Functionality** |
| **Reference** |  |
| **Objective** | Verify that application functionality is consistent with the behavior described in  the relevant requirements. |
| **Requirements verified** | • *TO17\_FUN\_20v1* – Vehicle Trajectory Planning Algorithm |
| **Brief**  **Description** | The project team will conduct a preliminary drive in the vehicle from the test start  point through the intersection to completion with the FHWA General Task  Manager to demonstrate the operational application for the scenario in which the vehicle comes to a full stop at a red light and must be re-engaged by the driver. This drive will be repeated for the remaining three (3) scenarios to demonstrate the full-functionality of the algorithm at different phases of the signal cycle. |
| **Entrance**  **Criteria** | The Test Driver must be seated in the driver’s seat. The Driver and all Passengers  must have their safety belts fastened.  Traffic control staff must be deployed and ready to monitor and manage traffic for the test runs. |
| **Configuration** |  |
| **Data Outputs** |  |

***EVALUATION PROCEDURES***

|  |
| --- |
| **Step Instruction Expected Outcome / Requirement Actual Result / Verified Pass or Fail** |
| **1** Turn on the tablet display using the power button, swipe right to unlock the screen and select the  “GlidePath” App Icon. |
| **2** Click “START Glidepath” and then select “OK.” |
| **3** Click “Navigate to Glidepath DVI.” |
| **4** Read the System Advisory and select “OK” to proceed with the test case. |
| **5** Select “20” for the Operational Speed using the down arrow. |
| **6** Verify that all elements of Activation Sequence are  Green and that Signal Status is actively counting  SPaT |
| **7** To start automated speed control, wait for the SPaT to read **0 seconds of Red** time and prepare to assume  manual steering and select “Go.” |
| **8** When there are 5 seconds of red remaining, a “GO”  button will flash green on the screen. Visually inspect  the intersection and surrounding area for safety conflicts and press “GO” on the DVI display when ready to proceed.  NOTE: The application will not resume until BOTH  the light turns green and the driver has selected GO. |

|  |  |  |  |
| --- | --- | --- | --- |
| **Step Instruction Expected Outcome / Requirement Actual Result /**  **Verified Pass or Fail** | | | |
| **9** After the vehicle passes through the intersection and approaches the Experimental End Location, the  application will automatically turn off EcoDrive and prompt the driver to resume Manual control. | | | |
| **10** When the DVI displays the following message: “Experiment ended; driver resume manual control,” tap the brake, shift to D and resume manual control of  the vehicle. | | | |
| **11** At the end of the experimental run, turn the vehicle around and return to the Experimental Start Location. | | | |
| **12** Repeat steps 2-11 for the remaining three scenarios using the start times in the table below. | ***TO17\_FUN\_20v1* – Vehicle Trajectory** | |  |
| **Planning Algorithm** |  | |
|  | | | |

|  |
| --- |
| **Scenario Scenario Signal Phase Signal**  **Number Description Timing** |
| **1** Maintain Speed Red 30 |
| **2** Speed Up Red 5 |
| **3** Full Stop Red 0 |
| **4** Slow Down Green 5 |

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| **Test Case #** | **TO17\_ALG\_02** |
| **Test Case** | **Demonstration of Algorithm Process** |
| **Reference** |  |
| **Objective** | Verify that the software components that address the algorithm-specific  requirements listed below both exist and function properly. |
| **Requirements verified** | • *TO17\_FUN\_16v1* – Application  • *TO17\_FUN\_27v1 –* Map Matching |
| **Brief**  **Description** | The project team will conduct a drive in the vehicle with the FHWA General Task  Manager with a remote connection to the in-vehicle PC to demonstrate the functionality of the individual software components listed above. |
| **Entrance**  **Criteria** | The Test Driver must be seated in the driver’s seat. The Driver and all Passengers  must have their safety belts fastened.  Traffic control staff must be deployed and ready to monitor and manage traffic for the test runs. |
| **Configuration** | • PC is configured to access the in-vehicle processor over 4G |
| **Data Outputs** |  |

REV 2.0 21 *GlidePath Prototype Requirements Compliance Test Plan*

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***EVALUATION PROCEDURES***

|  |  |  |
| --- | --- | --- |
| **Step Instruction Expected Outcome / Requirement Verified Actual Result / Pass or Fail** | | |
| **1** The **Driver** shall turn on the vehicle and manually drive to the start location. | | |
| **2** Initialize the Glidepath software via the DVI. | | |
| **3** Wait until the vehicle has computed a value for distance to This computation is required for Glidepath  stop bar. to start autonomous control and requires processed MAP data and GPS data to match  the vehicle to a lane.  ***TO17\_FUN\_27v1 –* Map Matching** | | |
| **4** Start the Glidepath run at one of the experimentally determined scenario start conditions. | | |
| **5** The **Driver** shall control the lateral motion of the vehicle for the duration of the run as well as engage manual override in the event of unsafe operation. | | |
| **6** The **Data Recorder** shall observe the vehicle’s behavior as it approaches the intersection. | | |
| **7** Reset conditions and conduct three more runs to demonstrate the remaining three algorithm scenarios. | | |
| **8 Post-Process** the logs generated during each scenario to see | ***TO17\_FUN\_16v1* – Application** |  |
| algorithm operation parameters, inputs, and outputs. | | |

**The signature below indicates acceptance of the Prototype as compliant with the requirements listed in this test case:**

FHWA GTM Signature Date GlidePath Project Lead Date

REV 2.0 22 *GlidePath Prototype Requirements Compliance Test Plan*

*Use, duplication, or disclosure is subject to the restrictions as stated on the cover page.*

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_DATA\_01** |
| **Test Case** | **Output Data Post-Processing** |
| **Reference** |  |
| **Objective** | Evaluate prototype data output logs to ensure all data requirements are met. |
| **Requirements verified** | • *TO17\_FUN12v1 –* Jerk Threshold  • *TO17\_FUN22v1* – DSRC Message Data  • *TO17\_FUN23v1* – Vehicle Positioning System  • *TO17\_FUN24v1* – Vehicle Longitudinal Control  • *TO17\_FUN25v1 –* MAP Parser  • *TO17\_FUN26v1 –* SPaT Parser  • *TO17\_DAT\_01v1 –* Data Logging Elements  • *TO17\_DAT\_02v1* – Data Logging Frequency  • *TO17\_DAT\_03v1* – Data Logging Time Protocol  • *TO17\_DAT\_04v1* – Data Storage |
| **Brief**  **Description** | The project team will provide an annotated sample of the output data along with an  actual output file from one of the test runs to both the evaluation team and FHWA General Task Manager to verify that all related data requirements are fulfilled by  the application. |
| **Configuration** |  |
| **Data Outputs** | Full log of live demonstrations as well as an annotated sample output log for cross-  reference. |

**Step Instruction Expected Outcome / Requirement Verified**

**Actual Result / Pass or**

**Fail**

**1** Connect to the GlidePath PC

via WinSCP the local IP

192.168.0.4

**2** Navigate to /opt/glidepath/logs ***TO17\_DAT\_04v1 –* Data**

**Storage**

**3** Open relevant .log file

**4** Compare with sample output below

**5** Review highlighted data elements in the sample data sets on the following pages

***TO17\_DAT\_01v1 – Data***

***Logging Elements***

***TO17\_FUN\_12v1 –* Jerk**

**Threshold**

***TO17\_FUN22v1* – DSRC Message Data**

***TO17\_FUN23v1 –* Vehicle**

**Positioning Data**

***TO17\_FUN24v1 –* Vehicle**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Longitudinal Control** | | |  | |  |
|  | | | | |
| ***TO17*\_*FUN25v1* – MAP** | | | |  |
| **Parser** |  | | | |
|  | | | | |
| **6** Review data logging frequency in logs to verify information is | ***TO17\_DAT\_02v1 –* Data** | | | |  | |
| **Logging Frequency** | |  | | | |
| recorded at least 1 Hz. | | | | | | |

**Figure 1. Annotated sample .log file output**

TIME\_SINCE\_FIRST\_MOTION 17.348

OPERATING\_SPEED 8.9408

SPEED\_COMMAND 11.06366

SMOOTHED\_SPEED 10.16474

SPEED 10.1618

ACCELERATION 0.245428

JERK -0.04297

LATITUDE 38.955

LONGITUDE -77.1478

DIST\_TO\_STOP\_BAR 116.1

SIGNAL\_PHASE GREEN SIGNAL\_TIME\_TO\_NEXT\_PHASE 12.9

SIGNAL\_TIME\_TO\_THIRD\_PHASE 15.9

MOTION\_STATUS Coast

LANE\_ID 12

CYCLE\_GPS 1

CYCLE\_MAP 31

CYCLE\_SPAT 33

CYCLE\_XGV 19

CYCLE\_EAD 1

CYCLE\_XGV\_COMMAND 24

XgvStatus{statusCode=READY, manualOverrideEngaged=false, safeStopPauseEngaged=false, safeStopStopEngaged=false, safeStopLinkStatus=1, externalSafeStopEngaged=false, computerSteeringControlEngaged=true, computerSpeedControlEngaged=false,

TO17\_FUN12v1

Jerk Threshold

TO17\_FUN22v1

DSRC Message

Data

TO17\_FUN23v1

Vehicle Positioning

Data

TO17\_FUN25v1

MAP Parser

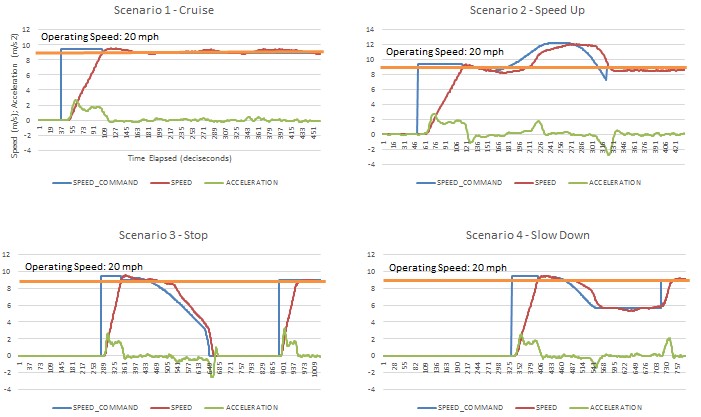
TO17\_FUN26v1

SPaT Parser

XGV\_STATUS

MAP\_MESSAGE SPAT\_MESSAGE STATUS\_MESSAGE

doorPauseEngaged=false, errorPauseEngaged=false, emergencyManualOverrideEngaged=false, steeringNeedsInitialization=false, steeringInitializationNeedsUserInput=false, on=true, mainFuelOrEnergyOn=true, auxiliaryEnergyOrFuelOn=false, autoStartInProgress=false, autoShutdownInProgress=false, parkingBrakeSet=false, hornEngaged=false, gear=DRIVE}



**Figure 2. Sample trajectories from experimental runs – *TO17\_FUN24v1* – Vehicle Longitudinal Control**

**The signature below indicates acceptance of the Prototype as compliant with the requirements listed in this test case:**

FHWA GTM Signature Date GlidePath Project Lead Date

## 2.5 Driver-Vehicle Interface

The various screens used in the Driver-Vehicle Interface will be printed for off-line review by the FHWA General Task Manager and used during the test drives for comparison.

|  |  |
| --- | --- |
| **Test Case #** | **TO17\_DVI\_01** |
| **Test Case** | **Driver-Vehicle Interface** |
| **Reference** |  |
| **Objective** | Verify that all DVI related requirements are met. |
| **Requirements verified** | • *TO17\_DVI\_01v1* – System Activation Switch  • *TO17\_DVI\_02v1* – System Status Indicator  • *TO17\_DVI\_03v1* – Intersection Departure Switch  • *TO17\_DVI\_04v1* – Signal Phase and Timing Display  • *TO17\_DVI\_05v1* – Motion Status Indicator  • *TO17\_DVI\_06v1* – Auditory Indicator  • *TO17\_DVI\_07v1* – Auditory Alert |
| **Brief**  **Description** | The project team will provide a printed copy of the various DVI screens for  preview by the FHWA General Task Manager to verify the content of the DVI and a specific test drive will be conducted to verify the compliance of the DVI  functionality in accordance with the requirements listed above. |
| **Entrance**  **Criteria** | The Test Driver must be seated in the driver’s seat. The Driver and all Passengers  must have their safety belts fastened.  Traffic control staff must be deployed and ready to monitor and manage traffic for the test runs. |
| **Configuration** | The vehicle should be at the Experimental Start Location, in Automated mode. |
| **Data Outputs** | Printed DVI material with annotations |

***EVALUATION PROCEDURES***

**Step Instruction Expected Outcome / Requirement Verified**

**Actual Result / Pass or**

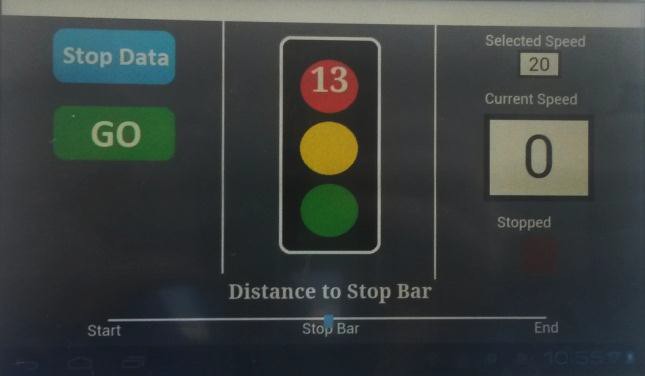
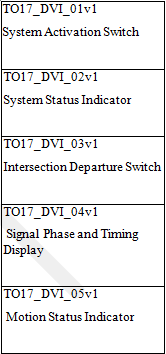
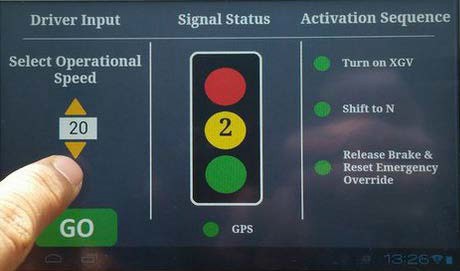
**Fail**

**1** With the vehicle in Automated mode at the Experimental Start Location, select the GlidePath application icon on the tablet display.

**2** Select “Start GlidePath” and click “OK” on the pop-up menu that reads “Successfully started GlidePath.”

Black main menu screen will appear

|  |
| --- |
| **Step Instruction Expected Outcome / Actual Result / Pass or**  **Requirement Verified Fail** |
| **3** Select “Navigate to GlidePath The “Authorized Users  DVI” and click “OK” after Only” page will display,  reading the advisory warning followed by the on the following page. operational speed  selection page |
| **4** Review the DVI screen (Screen  2) to ensure it is consistent with  the graphic and the relevant requirements listed below. |
| **5** Select the desired operational Application will engage, speed, prepare to control and DVI will change to  steering, and select “GO” Screen 3 |
| **6** Have a passenger review the  DVI screen (Screen 3) to ensure  it is consistent with the graphic and the relevant requirements listed below. |



**Figure 3. From top to bottom: DVI Screens 1-4**

**The signature below indicates acceptance of the Prototype as compliant with the requirements listed in this test case:**

FHWA GTM Signature Date GlidePath Project Lead Date

# 3.0 Requirements – Test Case Traceability Matrix

The following table is a comprehensive list of the requirements from the Final GlidePath Requirements document, version 6.1 dated April 20,

2015. Each line lists the Test Case Number for each requirement that has not been removed.

**Table 1. Requirement-Test Case Traceability Matrix**

|  |  |
| --- | --- |
| **Task Category ID Description Test Case # Test Case Name** | |
| **TO17** FUN 1 Automated Longitudinal Control TO17\_VEH\_03 Basic Longitudinal Control | |
| **TO17** FUN 2 Directional Control TO17\_VEH\_03 Basic Longitudinal Control | |
| **TO17** FUN 3 Automated Lateral Control TO17\_VEH\_03 Basic Longitudinal Control | |
| **TO17** FUN 4 Decoupled Longitudinal and Lateral Control TO17\_VEH\_03 Basic Longitudinal Control | |
| **TO17** FUN 5 Automated Control Switch TO17\_VEH\_04 Vehicle Behavior | |
| **TO17** FUN 6 Manual Override TO17\_VEH\_04 Vehicle Behavior | |
| **TO17** FUN 7 Additional Control Mechanism TO17\_VEH\_04 Vehicle Behavior | |
| **TO17** FUN 8 Emergency Stop Button REMOVED | |
| **TO17** FUN 9 Acceleration Control Commands TO17\_VEH\_01 Documentation of Vehicle Functionality | |
| **TO17** FUN 10 Deceleration Control Commands TO17\_VEH\_01 Documentation of Vehicle Functionality | |
| **TO17** FUN 11 Response Time | REMOVED |
| **TO17** FUN 12 Jerk Threshold TO17\_VEH\_04 Vehicle Behavior | |
| **TO17** FUN 13 Stopping Capability | REMOVED |
| **TO17** FUN 14 DSRC Communication TO17\_VEH\_02 In-Vehicle Equipment | |
| **TO17** FUN 15 Positioning TO17\_VEH\_02 In-Vehicle Equipment | |
| **TO17** FUN 16 Application TO17\_ALG\_02 Demonstration of Algorithm Process | |
| **TO17** FUN 17 Signal Control TO17\_INF\_01 Infrastructure Readiness | |
| **TO17** FUN 18 DSRC Communication (Infrastructure) TO17\_INF\_01 Infrastructure Readiness | |
| **TO17** FUN 19 In-Vehicle Processing TO17\_VEH\_02 In-Vehicle Equipment | |
| **TO17** FUN 20 Vehicle Trajectory Planning Algorithm TO17\_ALG\_01 Demonstration of Algorithm Functionality | |
| **TO17** FUN 21 Vehicle CANBus Data | REMOVED |
| **TO17** FUN 22 DSRC Message Data TO17\_DATA\_01 Output Data Post-Processing | |

|  |
| --- |
| **Task Category ID Description Test Case # Test Case Name** |
| **TO17** FUN 23 Vehicle Positioning System TO17\_DATA\_01 Output Data Post-Processing |
| **TO17** FUN 24 Vehicle Longitudinal Control TO17\_DATA\_01 Output Data Post-Processing |
| **TO17** FUN 25 MAP Parser TO17\_DATA\_01 Output Data Post-Processing |
| **TO17** FUN 26 SPaT Parser TO17\_DATA\_01 Output Data Post-Processing |
| **TO17** FUN 27 MAP Matching TO17\_ALG\_02 Demonstration of Algorithm Process |
| **TO17** BEH 1 Ignition to Park TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 2 Park to Manual TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 3 Park to Automated TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 4 Automated to Manual TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 5 Manual to Automated TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 6 Automated to EcoDrive TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 7 EcoDrive to Automated TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 8 EcoDrive to Idle TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 9 Idle to Automated TO17\_VEH\_04 Vehicle Behavior |
| **TO17** BEH 10 Idle to Manual TO17\_VEH\_04 Vehicle Behavior |
| **TO17** INT 1 Standard Wired Electrical Interface TO17\_VEH\_02 In-Vehicle Equipment |
| **TO17** INT 2 Standard Command Structure TO17\_VEH\_01 Documentation of Vehicle Functionality |
| **TO17** SEC 1 Physical Security TO17\_SEC\_01 Prototype Security |
| **TO17** SEC 2 Operational Security TO17\_SEC\_01 Prototype Security |
| **TO17** SEC 3 System Access TO17\_SEC\_02 PC Password Protection |
| **TO17** DVI 1 System Activation Switch TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DVI 2 System Status Indicator TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DVI 3 Intersection Departure Switch TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DVI 4 Signal Phase and Timing Display TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DVI 5 Motion Status Indicator TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DVI 6 Auditory Indicator TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DVI 7 Auditory Alert TO17\_DVI\_01 Driver-Vehicle Interface |
| **TO17** DAT 1 Data Logging Elements TO17\_DATA\_01 Output Data Post-Processing |

|  |
| --- |
| **Task Category ID Description Test Case # Test Case Name** |
| **TO17** DAT 2 Data Logging Frequency TO17\_DATA\_01 Output Data Post-Processing |
| **TO17** DAT 3 Data Logging Time Protocol TO17\_DATA\_01 Output Data Post-Processing |
| **TO17** DAT 4 Data Storage TO17\_DATA\_01 Output Data Post-Processing |

# Appendix A - GlidePath Security Protocol Agreement

**GLIDEPATH SECURITY PROTOCOL AGREEMENT**

This document outlines the required protocols to ensure secure and safe operation of the GlidePath Prototype Vehicle and Application. The signatories below document their agreement to abide by these protocols and to ensure that any new project staff members are trained accordingly.

I. Safety

The driver and all passengers SHALL wear safety belts when the vehicle is in motion.

II. System Access

The prototype platform (Linux PC) SHALL be protected by a single-layer authentication with a username and password to be shared only with project staff.

III. Physical Security

The prototype ignition and door key SHALL be stored in secured, locked location when not in use to avoid improper use by unauthorized personnel.

IV. Operational Security

The prototype SHALL NOT be left unattended while the vehicle is running to avoid improper use by unauthorized personnel.

The signatures below indicate the staff members who have been approved by the FHWA General Task Manager to operate the GlidePath Application. Any new users must be approved by the FHWA General Task Manager, trained by an approved operator, and must sign an addendum to this agreement to be stored on file with the FHWA General Task Manager.

Khalid Ahmad Date

Julie Evans Date

Christopher Armstrong Date

John Stark Date

Dave Ference Date

Kyle Rush Date

I, Osman Altan, authorize the project staff listed above to operate the GlidePath Prototype

Vehicle and Application.

FHWA GTM Signature Date

# Appendix B - Acronyms

|  |  |
| --- | --- |
| ASD | Aftermarket Safety Device |
| DSRC | Dedicated Short Range Communications |
| DVI | Driver-Vehicle Interface |
| GTM | General Task Manager |
| JAUS | Joint Architecture for Unmanned Systems |
| MPD | Motion Profile Driver |
| SPaT | Signal Phase and Timing |
| WSA | WAVE (Wireless Access for Vehicular Environments) Service Advertisement |