GlidePath Prototype Development

*Final Requirements Document*



**Project Number: DTFH61-12-D-00020**

**Submitted: 03 August 2016**

**Version: 8.0 DRAFT**

**Revisions**

|  |  |  |
| --- | --- | --- |
| Version | Date | Description of Change |
| 1.0 | 7/21/2014 | Initial Version |
| 2.0 | 8/14/2014 | Revised based on FHWA Comments |
| 3.0 | 8/20/2014 | Added Algorithm-specific Requirements |
| 4.0 | 9/2/2014 | Addressed comments on Algorithm-specific Requirements and all final comments |
| 5.0 | 9/16/2014 | Addressed final minor comments from FHWA for clarification. |
| 6.0 | 9/18/2014 | Addressed final additional minor comments from FHWA for clarification. |
| 7.0 | 11/18/2015 | Address acceptance test comment resolution matrix |
| 8.0 | 8/3/2016 | Expanded SPAT & MAP requirements to clarify that the system will sense any defined lane position and be able to use it for proper SPAT information. Removed extraneous requirement FUN-03. |

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# Introduction

This document contains the technical requirements for the GlidePath Prototype System that will be developed as part of the Saxton Lab Task Order 17 for the Federal Highway Administration’s Office of Operations, Research and Development (FHWA-HRDO). This project builds off of completed work that was funded by the U.S. Department of Transportation’s (USDOT’s) Applications for the Environment: Real-Time Information Synthesis (AERIS) Program in which the University of California at Riverside (UCR) developed an algorithm for the “Eco-Approach and Departure” of a vehicle approaching a signalized intersection with fixed-timing signal controls. The objective of the UCR algorithm was to reduce the fuel consumption of the vehicle by taking data input from vehicle sensors and roadside infrastructure to calculate an “eco-friendly” speed trajectory. The output speed trajectory was displayed on a tablet in the forward view of the driver as a green bar on a speedometer, such that the driver could accept the speed guidance to improve environmental performance of the vehicle. Preliminary field tests that were conducted in 2012 demonstrated reduced fuel consumption of up to eighteen (18) percent; however, the vehicle and equipment that was used to test the algorithm was never fully integrated into a unified system.

The purpose of Task Order 17 is to create a fully-integrated GlidePath Prototype that incorporates the UCR algorithm with a vehicle that is equipped with audio/visual display, communication, controller, processing, and positioning components. The new Prototype will implement the UCR algorithm output automatically, using computer-control of the vehicle’s longitudinal movement while the driver maintains control of steering and ensures safe operation of the vehicle along the roadway. Finally, Task Order 17 includes provision for field testing and demonstration of the GlidePath Prototype at the Turner-Fairbank Highway Research Center’s (TFHRC) Intelligent Intersection.

# Scope

The purpose of this document is to define a clear set of requirements that will be used as the basis for the Prototype design and implementation, as well as for the development of a test plan. These requirements are intended to ensure that all FHWA objectives are met by the design and that sufficient consideration is given to safety in the design and implementation of the Prototype. The scope of the Prototype is limited to a single vehicle that will operate on a single approach to a single, fixed time, signalized intersection that is sheltered from other traffic. These requirements define the functionality of the Prototype and all of its subsystems, and include the basic functionalities of the roadside infrastructure that is necessary to support the operation of the Prototype.

# System Description and Context

The GlidePath Prototype refers to a system comprised of the following subsystems that are integrated in a single vehicle to support the automated implementation of an Eco-Approach and Departure at a fixed-time intersection:

* **DSRC On-Board Unit (OBU)**
* **Advanced Positioning System**
* **Vehicle Network**
* **Automated Longitudinal Controller**
* **Driver-Vehicle Interface**

These subsystems are depicted in Figure 1, below, which also includes the relevant Roadside Infrastructure.

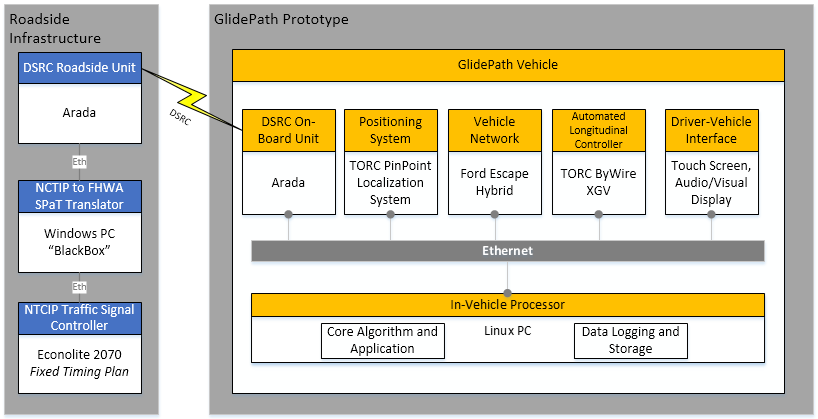


Figure 1. GlidePath Prototype Context Diagram

The GlidePath Prototype and its subsystems can be controlled by several input mechanisms that, in combination, serve as transitions between the vehicle states which are depicted in Figure 3.

Definition of Input Mechanisms:

* **Ignition Key** – physical mechanism to start/turn off the vehicle’s engine, located to the right of the steering wheel.
  + **Off** – when the key is in the “off” position, the vehicle’s engine is off and the vehicle will not move.



Activation Key

Figure . Picture of XGV Activation Key

* + **On** – when the key is in the “on” position, the vehicle’s engine will be turned on and the input mechanisms defined below will govern the movement of the vehicle.
* **Activation Key** – physical mechanism to activate XGV controller and provide power to the automated control systems. The key is located on lower right side of the center console in the front of the vehicle, as depicted in Figure 2.
  + **0** – when the key is in the “0” position, the automated systems are disabled and the vehicle operates in accordance with its stock functionality.
  + **1** – when the key is in the “1” position, the automated systems can be enabled by shifting the Gear Shift to the “N” position and can be activated through the DVI.
* **Gear Shift** – physical mechanism to switch between Parked, Manual and Automated states. When the vehicle ignition is turned off, the gear shift will be in the “P” position, when the vehicle ignition is turned on, the gear shift will behave in accordance with the following protocol:
  + **P** – when the gear shift is in the “P” position, the prototype will remain in the Parked state and the vehicle will not move.
  + **D** – when the gear shift is in the “D” position, the prototype will be in the “Manual” state and the vehicle will operate in accordance with its stock functionality.
  + **R** – when the gear shift is in the “R” position, the prototype will operate in accordance with its stock functionality.
  + **N** – when the gear shift is in the “N” position, the prototype will transition between the “Automated,” “EcoDrive,” and “Idle” states using input from the DVI, brake, and emergency button in accordance with the state transitions, depicted in Figure 3**Error! Reference source not found.**.
* **Brake Pedal** – the brake pedal is the physical mechanism located on the floor of the driver’s seat that can be used by the experimenter to reduce the speed of the vehicle when the ignition is turned on.
  + When the gear shift is in the “P”, “R”, or “D” positions, the brake pedal will operate in accordance with the vehicle’s stock functionality.
  + When the gear shift is in the “N” position, the brake pedal will operate in accordance with the vehicle’s stock functionality and will also serve as a manual override to deactivate the automated systems when depressed by the Experimenter.
* **Gas Pedal** – the gas pedal is the physical mechanism located on the floor of the driver’s seat that can be used by the Experimenter to increase the vehicle speed when the ignition is turned on.
  + When the gear shift is in the “D” position, the gas pedal will operate in accordance with the vehicle’s stock functionality.
  + When the gear shift is in the “N” position, the gas pedal will not control the vehicle speed.
* **Emergency Button** – the emergency button is a button that is located on the center console in the front of the vehicle and can be activated when the gear shift is in the “N” position.
  + When the prototype is in the “EcoDrive” state, the Experimenter can press the emergency button to manually override the automated systems with transition to the Idle state.
  + When the prototype is in the “Idle” state, the Experimenter can press and twist release the emergency button to transition to the “Automated” state.
* **Driver-Vehicle Interface (DVI)** – the DVI is the platform that will be used to accept inputs from the Experimenter to control the automated system.



Figure 3. GlidePath Prototype State Diagram

Table 1. Description of GlidePath Prototype Operating States

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| # | State Name | Definition | Ignition | Activation Key | Shift Position | Automated Control |
| 0 | Ignition Off | All systems are off. | Off | 0 | P | Disabled |
| 1 | Park | Vehicle engine is running, component systems power up, vehicle does not move. | On | 1 | P | Disabled |
| 2 | Manual | Driver has full control of the vehicle and is responsible for safe operation on the road. | On | 1 | D | Disabled |
| 3 | Automated | Automated control is enabled, but not engaged; user must initiate automated system or transition to manual control. | On | 1 | N | Enabled |
| 4 | EcoDrive | Automated control is engaged to control the longitudinal movement of the vehicle; driver must control lateral movement, re-engage automated control after a full stop, and revert to manual control as needed to ensure a safe demonstration of the prototype. | On | 1 | N | Actively Engaged |
| 5 | Idle | Automated controls have been disabled by driver intervention and must be reset before DVI can engage EcoDrive. In this State, the vehicle will revert to the stock vehicle “Neutral” operation. | On | 1 | N | Disabled |
| 6 | Idle with Brake | Automated controls are disabled and brake is gently applied to bring vehicle to a smooth stop. | On | 1 | N | Disabled |

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# Document Overview

# Requirements Nomenclature

The following section explains how the requirements nomenclature is constructed and numbered, as well as a description of the various methods used to verify compliance with each requirement.

The columns in the requirements tables throughout this document have the following definitions:

**ReqID –** Each requirement contains a unique ID for traceability and configuration management, beginning with “TO17” to designate the system being implemented under Task Order 17, followed by a three letter indicator of the requirement type (functional, behavioral, security, etc.), and terminated by the requirement ID number in the format XvY where “X” is the unique ID and “Y” is the version number.

Example: TO17\_FUN\_01v1 refers to the first version of a functional requirement with unique ID #01 for the system being implemented under Task Order 17.

**Description –** Statement of the function or conditions the system must meet to fulfill the research objectives of Task Order 17.

**Implementation Comment –** Any relevant information about the specific implementation selected for the GlidePath Prototype being developed for Task Order 17.

**Verification Method**- The method utilized to verify the function or condition. The four methods utilized to verify the function or conditions the system must meet are as follows:

1. **Documentation**: Verification of system functionality based on vendor documentation. This method will be used only to verify the functionality of commercial-off-the-shelf (COTS) system components.
2. **Visual and Audible Inspection:** Nondestructive examination of the system that may include simple physical manipulation and measurements.
3. **Demonstration:** Manipulation of the system as it is intended to be used to verify that the results are as planned or expected.
4. **Test:** Verification of the system using a controlled and predefined series of inputs, data, or stimuli to ensure that the system will produce a very specific and predefined output as specified by the requirements.

The requirements contained in this document SHALL be verified by the project team in accordance with a test plan that will be submitted for review and approval by FHWA.

# Conformance

Requirements listed in this document use the following terminology:

* **SHALL**: indicates that the definition is an absolute requirement of the specification.
* **SHALL NOT**: Indicates that the definition is an absolute prohibition of the specification.

# References

This section contains all referenced documents, and their appropriate versions, required to meet the specifications contained in this document. Listed documents that are not publicly available can be provided upon request.

| Reference Number | Document Name |
| --- | --- |
|  | FHWA Statement of Work for TOPR 17, version 4.0 dated February 20, 2014 |
|  | Leidos Proposal for Task Order 17 |
|  | TORC ByWire XGV User Manual, version 1.5 |
|  | Eco-Signal Operations: Operational Concept, Final Report – October 2013 |
|  | UCR’s Eco-Approach and Departure (EAD) Algorithm Report – August 2014 |
|  | SAE/TP 2009-01-3250 – Joint Architecture for Unmanned Systems: A Set of SAE Interoperability Standards |

# 

# System Requirements

This section contains the system requirements to meet FHWA specifications for the GlidePath Prototype. The requirements are broken down into the following categories:

* Functional
  + Vehicle
  + Intersection
  + Algorithm
* Behavioral
* Interface
* Security
* Driver-Vehicle Interface (DVI)
* Data Logging

# Functional Requirements

The functional requirements described below define the system components that are necessary to support the GlidePath Prototype. This section contains requirements for the vehicle’s automated control functions, including the physical input mechanisms that must be implemented on the Prototype. The behavior of each physical input mechanism is specified in Section 3.2.

The functional requirements provided below are organized based on the three primary system components: 1) vehicle, 2) infrastructure, and 3) algorithm.

**Vehicle**

| ReqID  (*Proposal Req’t Reference*) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_FUN\_01v1  (*GP\_Veh\_3*) | **Automated Longitudinal Control:** The prototype SHALL have full-range automated, computer-control of the vehicle’s longitudinal movement (speed) via an interface that controls the brakes and throttle of the vehicle. | The XGV’s automated controls can both bring the vehicle to a full stop and command the vehicle at any of its stock vehicle speeds. | Test |
| TO17\_FUN\_02v1  (*GP\_Veh\_4, GP\_Veh\_20*) | **Directional Control:** The prototype SHALL have the capability to move forward under automated, computer-control from a stopped position. |  | Documentation |
| TO17\_FUN\_03v1  (*GP\_Veh\_5*) | **Automated Lateral Control**  [Requirement Removed] |  |  |
| TO17\_FUN\_04v1  (*GP\_Veh\_6*) | **Decoupled Longitudinal and Lateral Control.** The prototype’s automated longitudinal and lateral control functions SHALL NOT be coupled, i.e., these functions can be enabled/disabled independent of each other. |  | Documentation |
| TO17\_FUN\_05v1  (*GP\_Veh\_7)* | **Automated Control Switch:** The prototype SHALL have a physical switch to enable automated control. | XGV has an “activation key” that must be switched from “0” to “1” to enable automated control. | Demonstration |
| TO17\_FUN\_06v1  (*GP\_Veh\_13*) | **Manual Override:** The prototype SHALL disable automated control of the vehicle when the brake pedal is depressed by the driver.  [*Note: the vehicle will return to manual driving mode when the gear shift is moved to “D”*] |  | Demonstration |
| TO17\_FUN\_07v1  (*GP\_Veh\_8)* | **Additional Control Mechanism:** The prototype SHALL have an additional mechanism for transferring to manual driving when the control switch is activated.  [*Note: the vehicle will return to manual driving mode when the gear shift is moved to “D”*] |  | Demonstration |
| TO17\_FUN\_08v1 | **Emergency Stop Button**  **[*Requirement Removed*]** |  |  |
| TO17\_FUN\_09v1  (*GP\_Veh\_14, GP\_Veh\_16*) | **Acceleration Control Commands:** The prototype SHALL have internal ‘closed-loop control’ to accelerate to a target speed by commanding the target speed and acceleration. | XGV ByWire Settings:   * Maximum Speed in forward direction: 46 meters/second * Maximum Speed in reverse direction: 10 meters/second * Maximum Acceleration in forward direction: 3 meters/second² * Maximum Acceleration in reverse direction: 2.7 meters/second² | Documentation |
| TO17\_FUN\_10v1  (*GP\_Veh\_15*) | **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. | XGV ByWire Settings:   * Maximum Speed in forward direction: 46 meters/second * Maximum Speed in reverse direction: 10 meters/second * Maximum Deceleration in forward direction: 9 meters/second² * Maximum Deceleration in reverse direction: 3.7 meters/second² | Documentation |
| TO17\_FUN\_11v1 | **Response Time**  **[*Requirement Removed*]** |  |  |
| TO17\_FUN\_12v1  *(GP\_Veh\_18)* | **Jerk Threshold:** The prototype SHALL have a jerk level of less than five (5) meters per second3 when achieving the prototype-driven target speed and acceleration. | Literature indicates that the maximum acceptable jerk may be 5 meters/second3. | Test |
| TO17\_FUN\_13v1 | **Stopping Capability**  **[*Requirement Removed*]** |  |  |
| TO17\_FUN\_14v1 | **DSRC Communication:** The prototype SHALL be equipped with a DSRC Aftermarket Safety Device (ASD) that is, at minimum, compliant with USDOT’s  *T-10001-T2-05\_ASD\_Device\_Design\_Specification\_20120109*. |  | Demonstration |
| TO17\_FUN\_15v1 | **Positioning:** The prototype SHALL be equipped with a positioning system that is capable of providing position and orientation feedback of the vehicle. | The TORC PinPoint Localization solution fuses inertial data from the vehicle with GPS data and is capable of receiving GPS corrections to provide filtered position and orientation information. | Demonstration |
| TO17\_FUN\_16v1 | **Application:** The prototype SHALL have an application that supports the core algorithm and provides interfaces to the prototype subsystems (e.g., localization, DSRC, vehicle controller) to handle inputs and outputs. |  | Test |

**Infrastructure**

| ReqID  (*Proposal Req’t Reference*) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_FUN\_17v1 | **Signal Control:** The supporting infrastructure SHALL include a fixed-time traffic light and signal controller capable of sending NTCIP Signal Phase and Timing (SPaT) format over Ethernet. | Multiple intelligent intersections may be aviailable. | Test |
| TO17\_FUN\_18v1 | **DSRC Communication:** The supporting infrastructure (i.e., test roadway and intersection) SHALL be equipped with a DSRC Roadside Unit (RSU) or set of RSUs that SHALL broadcast SPaT, WAVE Service Announcement (WSA), and Geographic ID (MAP) and is compliant with the USDOT’s  *T-10001-T2-05\_RSE\_Device\_Design\_Specification\_v30*. |  | Test |

**Algorithm**

| ReqID | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_FUN\_19v1 | **In-Vehicle Processing:** The prototype SHALL have an in-vehicle processor with an interface to the CAN bus, DSRC In-Vehicle Unit, a positioning system, and the vehicle’s longitudinal controller. | The in-vehicle processor is expected to be a Linux PC. |  |
| TO17\_FUN\_20v1 | **Vehicle Trajectory Planning Algorithm:** The prototype SHALL have a vehicle trajectory planning algorithm, consistent with UCR’s Eco-Approach and Departure (EAD) Algorithm and block diagrams in Appendix B, that calculates an eco-friendly speed trajectory for a vehicle approaching and departing the signalized intersection at TFHRC. |  |  |
| TO17\_FUN\_21v1 | **Vehicle CANbus Data:** The prototype SHALL utilize vehicle dynamics data from the vehicle CANbus, including Speed, RPM, and MAF, to be used as inputs to the Vehicle Trajectory Planning Algorithm. | Data is sent at least 1Hz. Data logging may be needed. | Demonstration |
| TO17\_FUN\_22v1 | **DSRC Message Data:** The prototype SHALL utilize data sent over DSRC, including the SPaT (10Hz) and GID/MAP (1Hz) messages, to be used as inputs to the Vehicle Trajectory Planning Algorithm. | Data logging may be needed. | Demonstration |
| TO17\_FUN\_23v1 | **Vehicle Positioning System:** The prototype SHALL utilize vehicle position information from the positioning system to be used as input to the Vehicle Trajectory Planning Algorithm. | Data is sent at least 1 Hz. Data logging may be needed. Onboard GPS or DSRC embedded secondary GPS could be used as Vehicle Location System. | Demonstration |
| TO17\_FUN\_24v1 | **Vehicle Longitudinal Control:** The prototype SHALL utilize the output target velocity data from the Trajectory Planning Algorithm as input to the longitudinal controller and the DVI. | Data will be send to vehicle longitudinal controller at least 1Hz. Data logging may be needed. | Demonstration |
| TO17\_FUN\_25v1 | **MAP Parser:** The prototype SHALL be able to parse MAP/GID messages and extract geometry information of the intersection that the control software is configured to listen to (the “selected intersection”). | MAPblob framework (FHWA-revised-version) is needed to parser MAP message. Data logging may be needed. |  |
| TO17\_FUN\_26v1 | **SPaT Parser:** The prototype SHALL be able to parse SPaT messages from the selected intersection and extract phase and timing information (current phase, time to next phase, time to next next phase) for the lane that the vehicle is currently in. | SPaTblob framework (FHWA-revised-version) is needed to parse SPaT message. Data logging may be needed. |  |
| TO17\_FUN\_27v1 | **MAP Matching:** The prototype SHALL do map matching and calculate the Distance to Stop Bar (DTSB) and identify the lane that the vechicle is traveling in for the selected intersection. |  |  |

# State Transition Requirements

The state diagram included in **Error! Reference source not found.** depicts the operational states of the GlidePath Prototype and recommended state transition mechanisms. The behavioral requirements included in this section define the transitions between each operational state.

Table 2. Available Input Mechanisms by State

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| State # | State Name | Gear Shift Position | Driver Input Mechanism | | | | | | | System Input Mechanism | |
| Ignition | Activation Key | Gear Shift | Brake Pedal | Gas Pedal | Steering | DVI | Brake Controller | Throttle Controller |
| 0 | Ignition Off | P | ✓ | ✓ |  |  |  |  |  |  |  |
| 1 | Park | P | ✓ |  | ✓ | ✓ |  |  |  |  |  |
| 2 | Manual | D |  |  | ✓ | ✓ | ✓ | ✓ |  |  |  |
| 3 | Automated | N |  |  | ✓ | ✓ |  | ✓ | ✓ |  |  |
| 4 | EcoDrive | N |  |  |  | ✓ |  | ✓ | ✓ | ✓ | ✓ |
| 5 | Idle | N |  |  | ✓ | ✓ |  | ✓ |  |  |  |

| ReqID  (*Proposal Req’t Reference*) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_BEH\_01v1 | **Ignition Off to Park:** The prototype SHALL transition from the “Ignition Off” to the “Park” state upon turning the vehicle on and switching the Activation Key to “1.” |  | Demonstration |
| TO17\_BEH\_02v1 | **Park to Manual:** The prototype SHALL transition from the “Park” to the “Manual” state upon pressing the brake pedal and moving the gear shift from the “P” into the “D” position. |  | Demonstration |
| TO17\_BEH\_03v1 | **Park to Automated:** The prototype SHALL transition from the “Park” to the “Automated” state upon pressing the brake pedal and moving the gear shift from the “P” into the “N” position. |  | Demonstration |
| TO17\_BEH\_04v1 | **Automated to Manual:** The prototype SHALL transition from the “Automated” to the “Manual” state upon pressing the brake pedal and moving the gear shift from the “N” position into the “D” position or moving the gear shift from “N” position into the “D” position, either from a mobile or stationary position. |  | Demonstration |
| TO17\_BEH\_05v1 | **Manual to Automated:** The prototype SHALL transition from the “Manual” to the “Automated” state upon pressing the brake pedal to bring the vehicle to a complete stop and moving the gear shift from the “D” position to the “N” position. |  | Demonstration |
| TO17\_BEH\_06v1 | **Automated to EcoDrive:** The prototype SHALL transition from the “Automated” to the “EcoDrive” state upon driver input to the DVI to indicate “GO.”  *Note: the specific driver input and indicator will be defined in a subsequent version of this document.* |  | Demonstration |
| TO17\_BEH\_07v1 | **EcoDrive to Automated:** The prototype SHALL transition from the “EcoDrive” to the “Automated” state upon driver input to the DVI to indicate “STOP.”  *Note: the specific driver input and indicator will be defined the system architecture and design documents.* | This transition to the “Automated” state will result in the vehicle coasting until the driver shifts from “Automated” to “Manual” | Demonstration |
| TO17\_BEH\_08v1 | **EcoDrive to Idle:** The prototype SHALL transition from the “EcoDrive” to the “Idle” state upon use of the brake pedal or pressing the emergency button. |  | Demonstration |
| TO17\_BEH\_09v1 | **Idle to Automated:** The prototype SHALL transition from the “Idle” to the “Automated” state upon pressing and releasing the emergency button. |  | Demonstration |
| TO17\_BEH\_10v1 | **Idle to Manual:** The prototype shall transition from the “Idle” to the “Manual” state upon moving the gear shift to the “D” position. | “Idle” occurs after the driver applies the brake or hits the emergency button while in “Automated” or “EcoDrive” | Demonstration |

# Interface Requirements

| ReqID  (*Proposal Req’t Reference*) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_INT\_01v1  (*GP\_Veh\_1*) | **Standard Wired Electrical Interface:** The prototype SHALL utilize an Ethernet interface for communicating with the in-vehicle processor. | Ethernet | Documentation |
| TO17\_INT\_02v1  (*GP\_Veh\_2*) | **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. | JAUS via Ethernet | Documentation |

# Security Requirements

The security requirements described below define the system components that are necessary to support the GlidePath Prototype.

| ReqID  (*Proposal Req’t Reference*) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_SEC\_01v1 | **Physical Security:** The prototype ignition and door key SHALL be stored in a secured, locked location when not in use to avoid improper use by unauthorized personnel. |  | Documentation |
| TO17\_SEC\_02v1 | **Operational Security:** The prototype SHALL NOT be left unattended while the vehicle is running to avoid improper use by unauthorized personnel. |  | Documentation |
| TO17\_SEC\_03v1 | **System Access:** The prototype platform (i.e., Linux PC) SHALL be protected by single layer authentication with a username and password. |  | Test |

# Driver Vehicle Interface (DVI) Requirements

The DVI requirements described below define the system components that are necessary to support the GlidePath Prototype. Additional requirements may be added in subsequent revisions of this document.

| ReqID  (*Proposal Req’t Reference*) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_DVI\_01v1  *(GP\_DVI\_1)* | **System Activation Switch:** The DVI SHALL have a mechanism to engage/disengage the EcoDrive state. |  | Demonstration |
| TO17\_DVI\_02v1  *(GP\_DVI\_2)* | **System Status Indicator:** The DVI SHALL have a visual indicator within the forward view of the Experimenter that depicts the current state of the system (enabled/disabled). |  | Demonstration |
| TO17\_DVI\_03v1  *(GP\_DVI\_3)* | **Intersection Departure Switch:** The DVI SHALL have a ‘GO’ button (i.e., software or hardware-enabled) within the forward view of the Experimenter to initiate the Intersection Departure from a full-stop at the intersection when the traffic light turns from RED to GREEN. |  | Demonstration |
| TO17\_DVI\_04v1  *(GP\_DVI\_4)* | **Signal Phase and Timing Display:** The DVI SHALL have a visual indicator within the forward view of the Experimenter to provide Signal Phase and Timing information to the driver. |  | Demonstration |
| TO17\_DVI\_05v1  *(GP\_DVI\_5)* | **Motion Status Indicator:** The DVI shall have a visual indicator within the forward view of the Experimenter that depicts the status of the vehicle motion as controlled by the automated controller. | Example protocol:   * Blue: Coasting * Green: Accelerating * Yellow: Braking * Red: Stopped | Demonstration |
| TO17\_DVI\_06v1  *(GP\_DVI\_6)* | **Auditory Indicator:** The DVI SHALL have a mechanism to provide auditory feedback to the Experimenter. | The team anticipates that the auditory indicator will be implemented via software such that the auditory alerts can be modified if necessary. | Demonstration |
| TO17\_DVI\_07v1 | **Auditory Alert:** The DVI SHALL provide an auditory alert to the Experimenter at least 3 seconds prior to a system change that will require the Experimenter’s input (e.g., traffic signal phase change from RED to GREEN) | The team anticipates that the auditory indicator will be implemented via software such that the auditory alerts can be modified if necessary. | Demonstration |
| TO17\_DVI\_08v1 | **Experiment Termination:** When “EcoDrive OFF” is selected, the prototype SHALL turn off the application and notify the driver to resume manual control of the vehicle. |  | Demonstration |

# Data Logging Requirements

The requirements described below define the data logging capabilities that are necessary to support the GlidePath Prototype.

| ReqID  (RFP Req’t Reference) | Description | Implementation Comments | Verification Method |
| --- | --- | --- | --- |
| TO17\_DAT\_01v1 | **Data Logging Elements:** The prototype SHALL be capable of logging the vehicle data outlined in Table 3. | The DSRC roadside unit logs data locally. A logging solution will be implemented to record vehicle and algorithm feedback data. | Demonstration |
| TO17\_DAT\_02v1 | **Data Logging Frequency:** The data logging capability SHALL record information at least 1Hz. |  | Demonstration |
| TO17\_DAT\_03v1 | **Data Logging Time Protocol:** The data logging capability SHALL utilize a common system time for all information recorded from prototype components to support time synchronization. | The localization solution has an NTP server which provides UTC as the common time across all system components for time synchronization purposes | Demonstration |
| TO17\_DAT\_04v1 | **Data Storage:** The data logging capability SHALL write specified data elements to local storage to support download for analysis and post-processing. | Depending on the data logging solution, the prototype may store data from all system components to the same database or may store individual files from each system component to be integrated in post-processing. | Demonstration |

Table 3. Data Logging - Specified Data Elements by System Component.

| Source | Data Elements |
| --- | --- |
| Vehicle Feedback Data Logging | Throttle Position  Brake Position  Brake Master Cylinder Pressure Signal  Steering Angle  Transmission Gear  Vehicle Speed  Individual Wheel Speed  Parking Brake  Door Ajar  Fuel Level  12V Battery Voltage |
| Communication Feedback Data Logging | Signal Phase and Timing (SPaT) information capture  Geographic ID (MAP) information capture  WAVE service announcement (WSA) information capture |
| Application Feedback Data Logging | EcoDrive application status (i.e., enabled or disabled)  EcoDrive application run time |
| Algorithm Feedback Data Logging | **Inputs Received by Algorithm**  Instant location  Distance to intersection *(derived)*  Instant vehicle speed  Signal phase and timing (SPaT) information received by algorithm  Acceleration  Deceleration  Jerk *(derived from Acceleration/Deceleration)*  **Outputs Provided by Algorithm**  Vehicle trajectory in the subsequent time window (i.e., vehicle speed and acceleration at each time step) |

## Appendix A – FHWA Requirements

Items highlighted red in the table below were removed from consideration in the GlidePath Prototype implementation at the approval of FHWA.

| **Vehicle Requirements** | **Technical Requirement** | | **“SAIC” Team Comment** | |
| --- | --- | --- | --- | --- |
| **Vehicle Requirements** | | | | |
| GP\_Veh\_1 | The test vehicle SHALL have an industry standard wired electrical/electronic interface that is capable of communicating with the control computer provided by the PD Contractor | | Accepted | |
| GP\_Veh\_2 | The test vehicle SHALL have an industry standard command structure or a well-defined command format designed by the PD Contractor enabling control commands to be sent to control the vehicle in real-time | | Follow up with FHWA | |
| GP\_Veh\_3 | The test vehicle SHALL have automatic longitudinal control capability via the interface that controls the throttle and brakes of the vehicle | | Change to Automated | |
| GP\_Veh\_4 | The test vehicle SHALL have the capability to move in forward or backward direction under automatic computer control | | Accepted | |
| GP\_Veh\_5 | The test vehicle may have lateral control capability via the interface that controls the steering which will not be used in this project | | Accepted | |
| GP\_Veh\_6 | The test vehicle’s automatic longitudinal and lateral control functions SHALL be decoupled, i.e., these functions can enabled/disabled independent of each other, either manually via switch(s) or automatically via command through the control computer | | Change to automated, accepted | |
| GP\_Veh\_7 | The test vehicle SHALL have a manual switch that controls the operating mode of the vehicle as manually driven or automatically controlled | | Accepted, control using the gear shift which is standard on XGV | |
| GP\_Veh\_8 | The test vehicle may have another switch for transferring the mode to manual when activated | | Accepted, emergency override and brake pedal will be implemented on XGV | |
| GP\_Veh\_9 | The test vehicle SHALL have an ‘emergency’ push-button that stops the vehicle immediately when activated | | Accepted | |
| GP\_Veh\_10 | The operator SHALL be able to supplement automatic braking in the test vehicle by pressing the brake pedal beyond the current braking level | | Clarify with FHWA that braking is either Automatic or Manual - you can't "supplement" automatic braking without reverting to manual mode | |
| GP\_Veh\_11 | The operator SHALL be able to override automatic acceleration in the test vehicle by pressing the brake pedal, and during this manual action the throttle of the vehicle SHALL be released to assume ‘fully closed-throttle’ state or ‘idle’ state | | Outside of scope - discuss potential for modification with FHWA | |
| GP\_Veh\_12 | The operator SHALL be able to supplement automatic acceleration in the test vehicle by pressing the accelerator pedal, and the throttle SHALL assume the ‘fully closed-throttle’ state or ‘idle’ state after the operator releases the accelerator pedal | | Discuss with FHWA | |
| GP\_Veh\_13 | As stated above, the test vehicle SHALL revert back to manual mode if the operator touches the brake or accelerator pedal during the automatic mode | | Separate into two requirements - discuss throttle | |
| GP\_Veh\_14 | The test vehicle SHALL have the capability to be controlled to accelerate to a target speed by commanding the target speed and acceleration, within the capabilities of the vehicle | | Accept | |
| GP\_Veh\_15 | The test vehicle SHALL have the capability to be controlled to decelerate to a target speed by commanding the target speed and deceleration, within the capabilities of the vehicle | | Accept | |
| GP\_Veh\_16 | The test vehicle SHALL have internal ‘closed-loop control’ to achieve the longitudinal control variables within acceptable limits | | Define "acceptable limits" | |
| GP\_Veh\_17 | The test vehicle SHALL have an acceptable response time | | Define "acceptable" | |
| GP\_Veh\_18 | The test vehicle SHALL have an acceptable ‘jerk’ level when achieving the target speed/acceleration | | Look into Human Factors research for "acceptable" jerk levels | |
| GP\_Veh\_19 | The test vehicle SHALL be able to come to a full stop under automatic control and SHALL be able to hold the vehicle indefinitely at stopped state | | Accept | |
| GP\_Veh\_20 | The test vehicle SHALL be able to move forward or backward under automatic control from stopped state | | See GP\_Veh\_4 | |
| **DVI Requirements** | | | | |
| GP\_DVI\_1 | The DVI SHALL have a Eco System enable (engage) / disable (disengage) switch (toggle) | | “SAIC” team will implement a physical on/off switch for the application | |
| GP\_DVI\_2 | The DVI SHALL have a visual indicator (e.g., LED) clearly indicating the state of the system (enabled/disagled) and should be located in the vicinity of the system enable/disable switch | | “SAIC” team will implement LED state indicators near the on/off switch | |
| GP\_DVI\_3 | The DVI SHALL have a ‘GO’ switch (momentary/push-button). The purpose of this button is for the Experimenter to initiate Intersection Departure when the vehicle is automatically stopped at the intersection and the traffic light turns from RED to GREEN state | | “SAIC” team will implement a ‘go’ button to resume automatic operation after a full stop | |
| GP\_DVI\_4 | The DVI SHALL have a visual indicator (e.g., LED) giving feedback to the Experimenter that the traffic light turned from RED to GREEN state and the Experimenter should press the GO switch. This indicator should be located in the vicinity of the GO switch. The visual indicator SHALL be activated TBD seconds before the traffic light turns from RED to GREEN. The driver then has time to respond to push the GO switch and allow the vehicle accelerate through the intersection as soon as the traffic light turns GREEN without any loss of time. | | “SAIC” team will implement a visual indicator to alert the driver to an upcoming phase transition from red to green | |
| GP\_DVI\_5 | The DVI SHALL have a row of three indicators (e.g., LED’s) that indicate state of the system while the system is active. These indicators SHALL give visual feedback to the Experimenter as; (i) prototype vehicle is coasting (constant speed), (ii) prototype vehicle is accelerating, (iii) prototype vehicle is decelerating | | “SAIC” team will implement visual system status indicators | |
| GP\_DVI\_6 | The DVI SHALL have a two tone aural device to provide feedback to the driver when the system changes state (e.g., system changes states between coasting, accelerating, decelerating) or needs Experimenter’s attention (e.g., traffic state changed from RED to GREEN) | | “SAIC” team will implement a two-tone aural indicator to provide audible alerts to the driver | |
|  |  |  | |  |

## Appendix B – Vehicle Trajectory Planning Algorithm (VTPA)

Level 1 Block Diagram



Level 2 Block Diagram

