



UNITED STATES
DEPARTMENT OF TRANSPORTATION



Eco-Signal Operations Concept of Operations (ConOps)

Applications for the Environment: Real-Time Information Synthesis (AERIS) Program

Fall/Winter Webinar Series

November 14th, 2012

Presentation Overview

1. **Background – Transportation and the Environment**
2. **Description of the Current Situation**
3. **Limitations of Current Systems**
4. **Eco-Signal Operations Transformative Concept**
5. **Scenarios**
6. **Goals, Objectives, and Performance Measures**



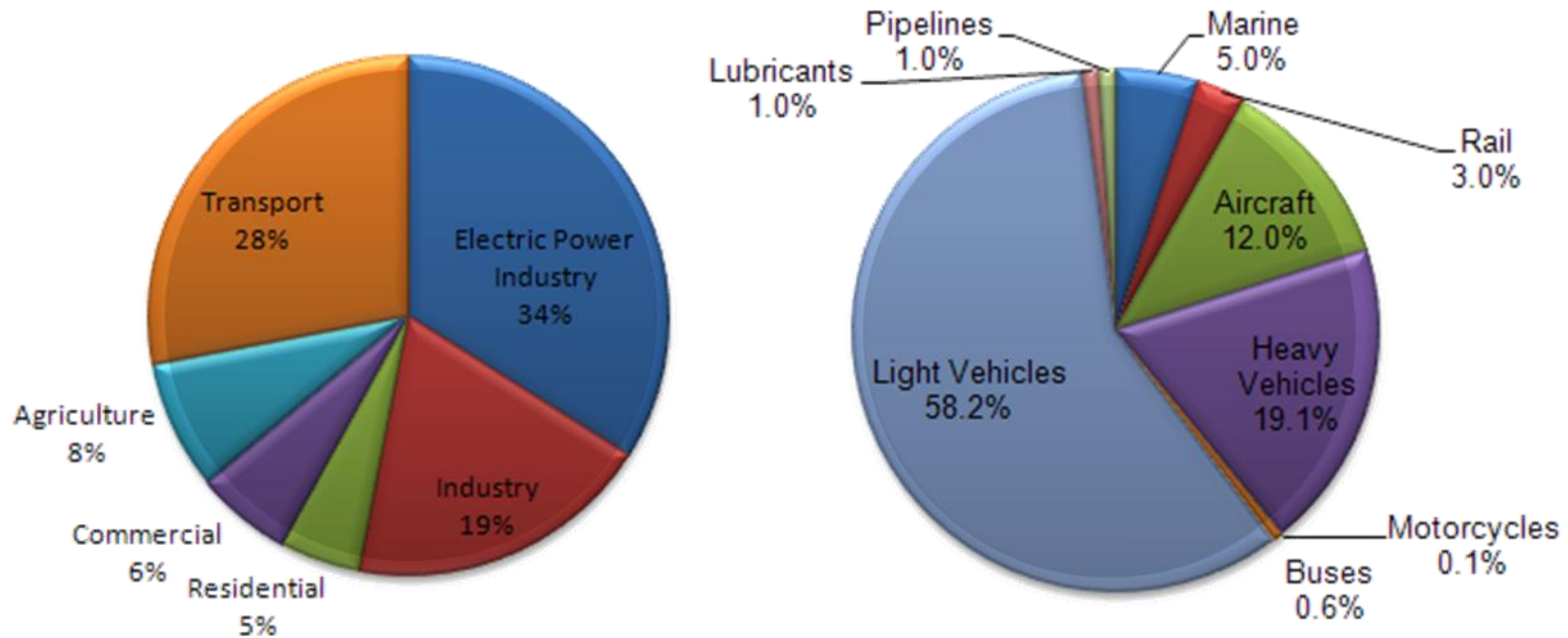
The Eco-Signal Operations ConOps

- Focuses on environmental applications at signalized intersections
 - Mobility applications are being researched by the DMA Program
- Provides an operational description of “how” the Transformative Concept may operate.
- Communicates user needs and desired capabilities for and expectations of the Eco-Signal Operations Transformative Concept .
- Builds consensus among AERIS user groups and stakeholders concerning these needs and expectations.
 - USDOT
 - State and Local Departments of Transportation (DOTs)
 - Regional Planning Organizations
 - The Automotive Industry
 - ITS Developers, Integrators, and Researchers
- Serves as a guideline moving forward with research and development of AERIS applications.



1. BACKGROUND

Transportation and the Environment



Transportation is the “fastest-growing source of U.S. GHG emissions, accounting for 47 percent of the net increase in total U.S. emissions since 1990, and is the largest end-use source of CO₂, which is the most prevalent GHG.”

- Environmental Protection Agency (EPA)

Transportation and the Environment *(cont'd)*

- Increase in emissions from transportation from 1990 to 2008 can be attributed to:
 - A 37 percent increase in light-duty vehicle miles traveled (VMT) due to:
 - Population Growth
 - Economic Growth
 - Urban Sprawl
 - Low Fuel Prices
 - While the total average fuel economy of vehicles increased during this time, the average fuel economy of vehicles sold during this time decreased
 - Light duty trucks, including sport utility vehicles, accounted for more than half of the vehicle market in 2004

As VMT and sales of vehicles with poor fuel economy increased, petroleum consumption also increased, which led to an increase in emissions

Strategies for Reducing Surface Transportation-Related Emissions

Strategy #1

Vehicle Technology

- Improve the energy efficiency of the vehicle fleet by implementing more advanced technologies

Strategy #2

Fuel Technology

- Reduce the carbon content of fuels through the use of alternative fuels (for instance, natural gas, biofuels, and hydrogen)

Strategy #3

Travel Activity

- Reduce the number of miles traveled by vehicles, or shift those miles to more efficient modes of transportation

Strategy #4

Vehicle and System Operations

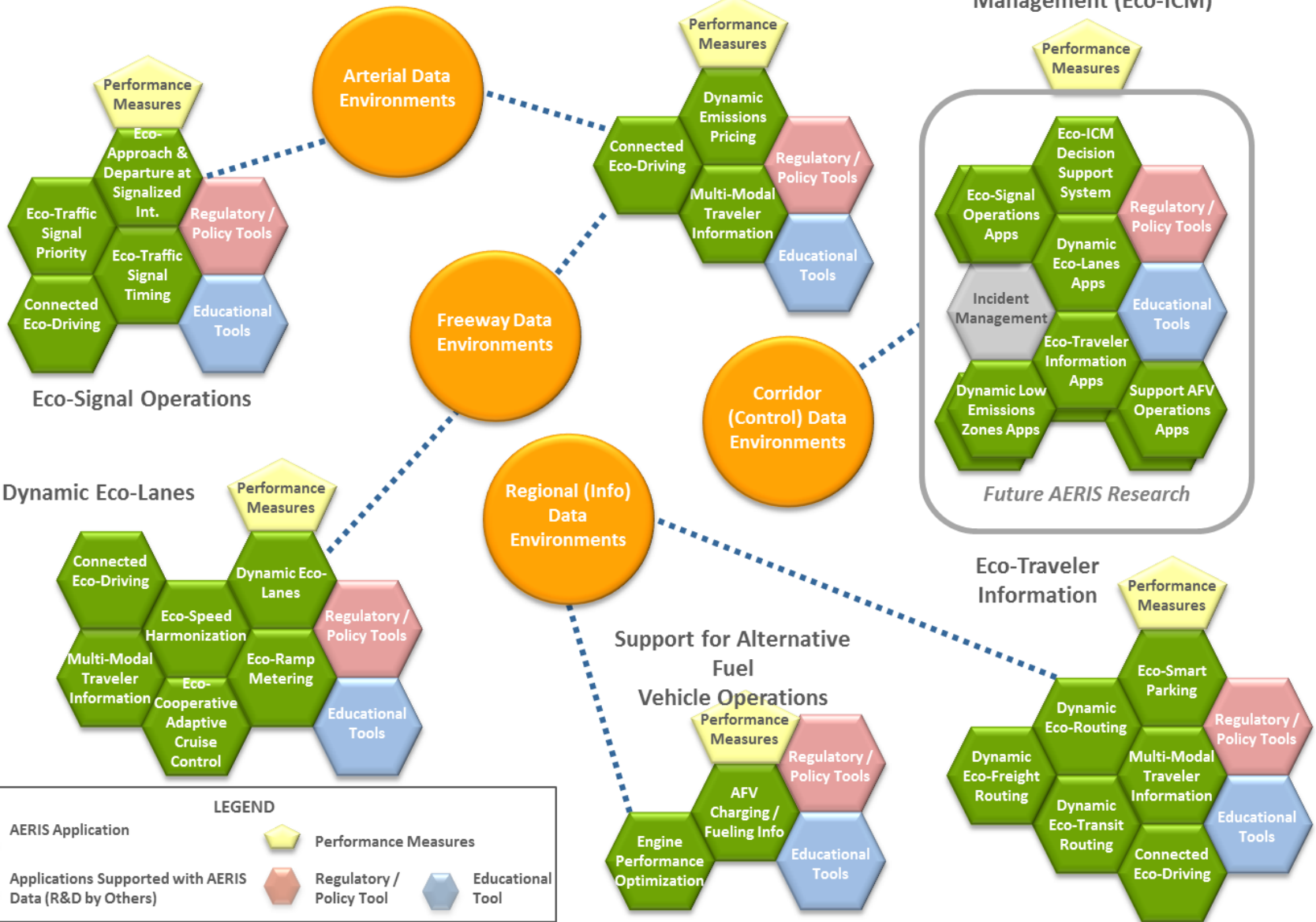
- Improve the efficiency of the transportation network so that a larger share of vehicle operations occur in favorable conditions, with respect to speed and smoothness of traffic flow, resulting in more fuel efficient vehicle operations





AERIS TRANSFORMATIVE CONCEPTS

Cleaner Air Through Smarter Transportation



2. DESCRIPTION OF THE CURRENT SITUATION



Traffic Signal Timing Fundamentals

▪ Fixed Timed Operation

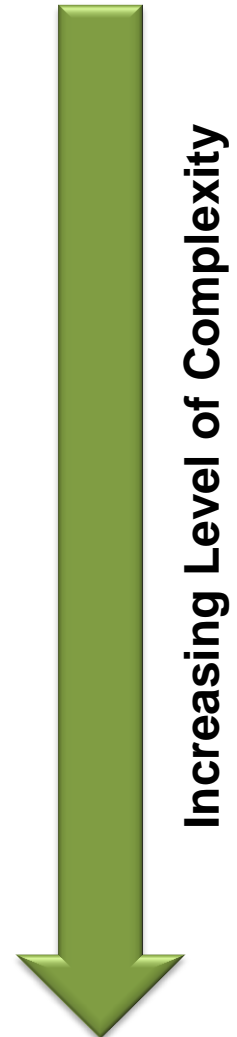
- Does not require traffic detectors at the intersection
- Includes a set programmed time to service all movements every cycle
- Services all movements whether or not there is vehicle demand
- Assumes that the traffic patterns can be predicted based on time of day

▪ Actuated Operation (Semi-Actuated or Fully Actuated)

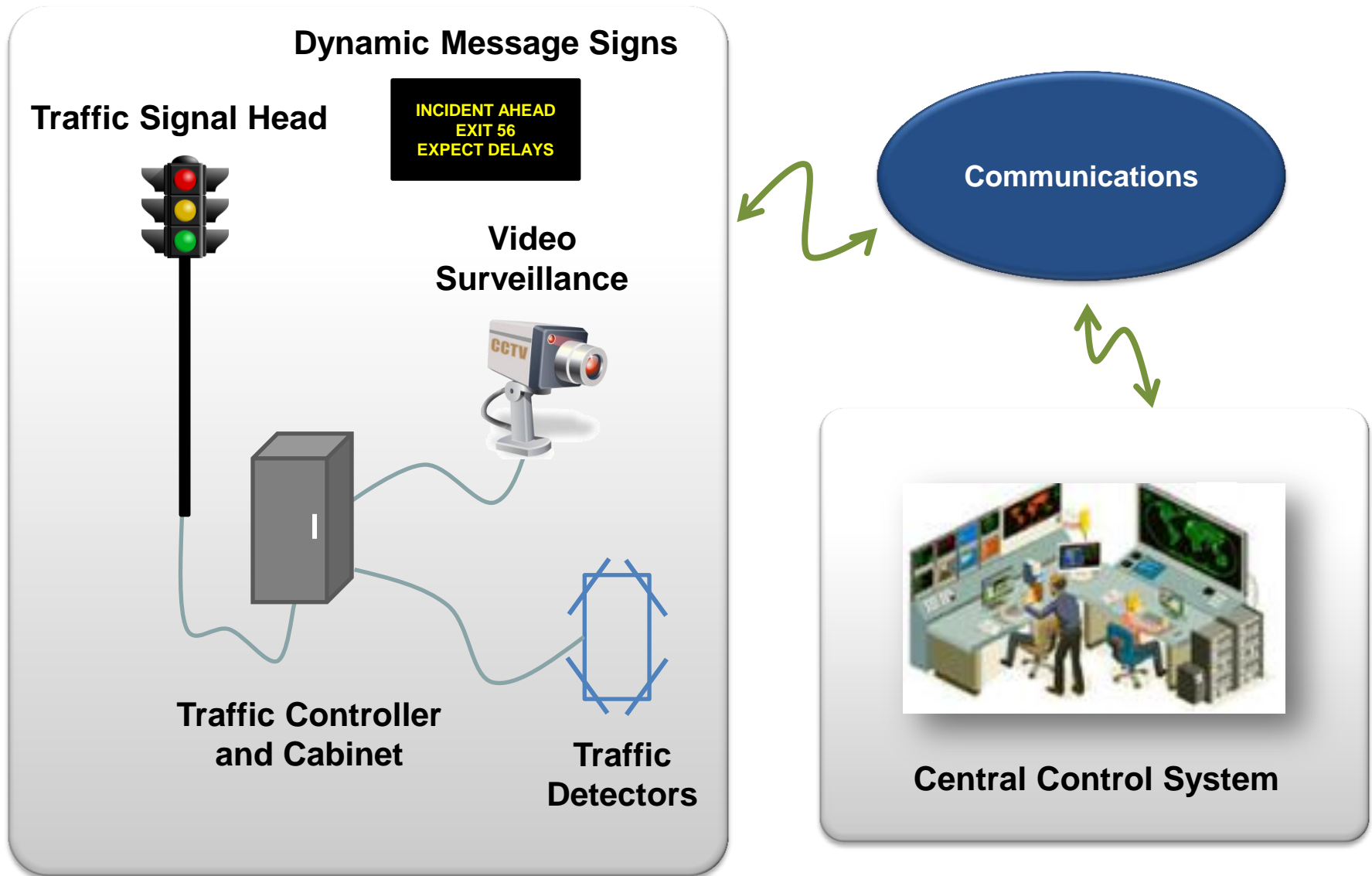
- Consists of actuated traffic signal controllers and traffic detectors placed in or on the roadways approaching the intersection
- Primarily concerned with when green intervals terminate
 - Maximum Green Time
 - Traffic Flow Ceases on the Approach
 - Force-off by the Signal System
 - Traffic Signal Pre-emption

▪ Adaptive Signal Operation

- Consists of adaptive traffic control system and traffic detectors placed in or on the roadways approaching the intersection
- Coordinates control of traffic signals across a signal network, adjusting the lengths of signal phases based on prevailing traffic conditions



Central Control Systems



Environmental Benefits from Current Systems

- The 2007 National Traffic Signal Report Card estimated that “updating signal timing costs less than \$3,000 per intersection,” can reduce emissions up to 22%, and has a high return on investment.

- A number of traffic **signal coordination** projects in the United States have documented emissions savings. Some examples include:
 - **Syracuse, New York** | The implementation of traffic signal coordination reduced emissions by 9 to 13%, reduced delays by 14 to 19%, and increased the average speed by 7 to 17%.
 - **St. Augustine, Texas** | Traffic signal coordination resulted in a savings of 26,000 gallons of fuel, reduced delays by 36%, and saved \$1.1 million.
 - **Los Angeles, California** | Emissions reductions of 14% and a reduction of fuel by 13% were achieved by implementing traffic signal coordination.
 - **Oakland County, Michigan** | The County’s traffic signal coordination project reduced CO by 1.7 to 2.5 percent, NOx by 1.9 to 3.5%, and reduced fuel consumption by 2.7 to 4.2%.



Environmental Benefits from Current Systems

▪ Adaptive Signal Operations

- **Tucson, Arizona** | Models indicated adaptive signal control could decrease delay for travelers on the main street by 18.5% while decreasing delay for travelers on cross-streets by 28.4%.
- **Los Angeles, California** | Adaptive signal control systems improved travel time by 13%, decreased stops by 31%, and reduced delay by 21%.
- **The University of Virginia** | Simulation study found that adaptive signal control reduced delay by 18 to 20% when compared to fixed-time signal control.
- **Lee's Summit, Missouri** | An adaptive traffic signal system was implemented on a 2.5-mile arterial with 12 signals.
 - Emissions either increased or decreased depending on whether or not the signal favored the direction of travel.
 - When traveling in the direction favored by the signal, emissions decreased.
 - When traveling in the direction not favored by the signal, emissions ranged from an increase of 9% to a decrease of 50%.



3. LIMITATIONS OF CURRENT SYSTEMS

Limitations of Current Systems

1. Current systems are limited by the data collected from infrastructure-based sensors
2. Current systems do not collect and use (or collect and use minimal) environmental data
3. Emissions data are not collected from vehicles
4. The majority of traffic signal systems are not optimized in “real-time”
5. Adaptive traffic signal systems require an extensive amount of infrastructure-based sensors per approach
6. Current traffic signal systems are generally optimized for mobility, not the environment
7. Current traffic signal priority applications do not consider environmental impacts at the signalized intersection
8. Current traffic signal systems do not provide information to drivers to support eco-driving
9. Electric vehicles are not capable of charging their batteries as they wait at signalized intersections

Connected vehicle technologies can help address these limitations



Connected Vehicles

Data Sent from the Vehicle

Real-time location, speed, acceleration, emissions, fuel consumption, and vehicle diagnostics data



Data Provided to the Vehicle

Real-time traffic information, safety messages, data from other vehicles (e.g., location, speed, etc.), signal phase and timing (SPaT) messages, and geographic information descriptions (GIDs)

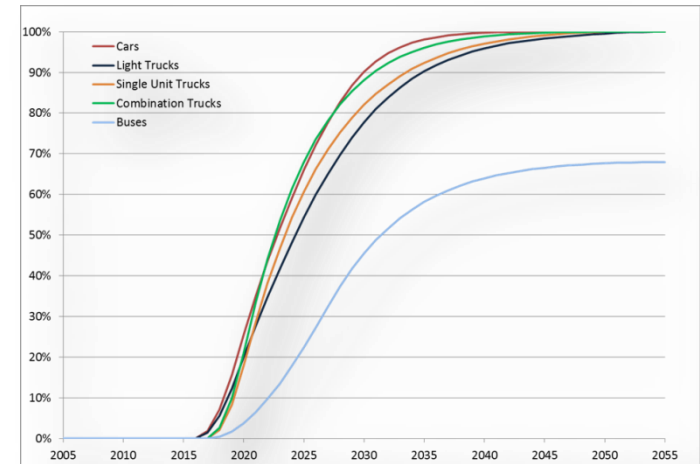
Improved Powertrain

More fuel efficient powertrain including; hybrids, electric vehicles, and other alternative power sources

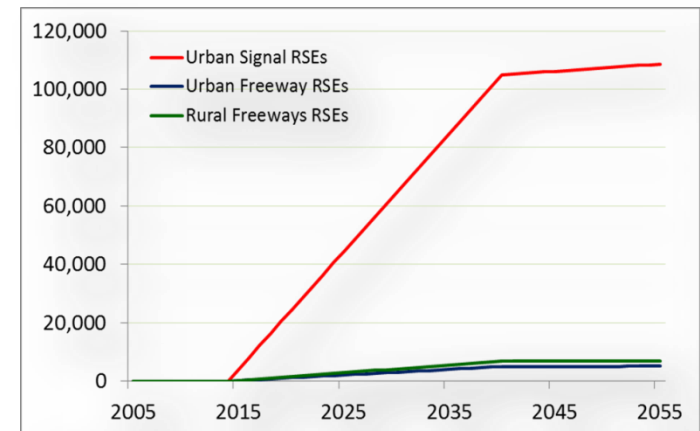


Deployment Rates and Market Penetration

- The market penetration of connected vehicle technologies is expected to take time to achieve comprehensive deployment.
- Infrastructure deployed during this transition must continue to support the environmental needs of non-equipped vehicles while leveraging the capabilities of connected vehicles to realize the benefits of vehicle-to-infrastructure (V2I) communications.
- The first generation of V2I applications will build upon current infrastructure systems for non-equipped vehicles, while at the same time providing data and information to connected vehicles to support better situational awareness and more informed decisions.



Estimated OBE Deployment Rate



Estimated RSE Deployment Rate





4. ECO-SIGNAL OPERATIONS TRANSFORMATIVE CONCEPT

Eco-Signal Operations

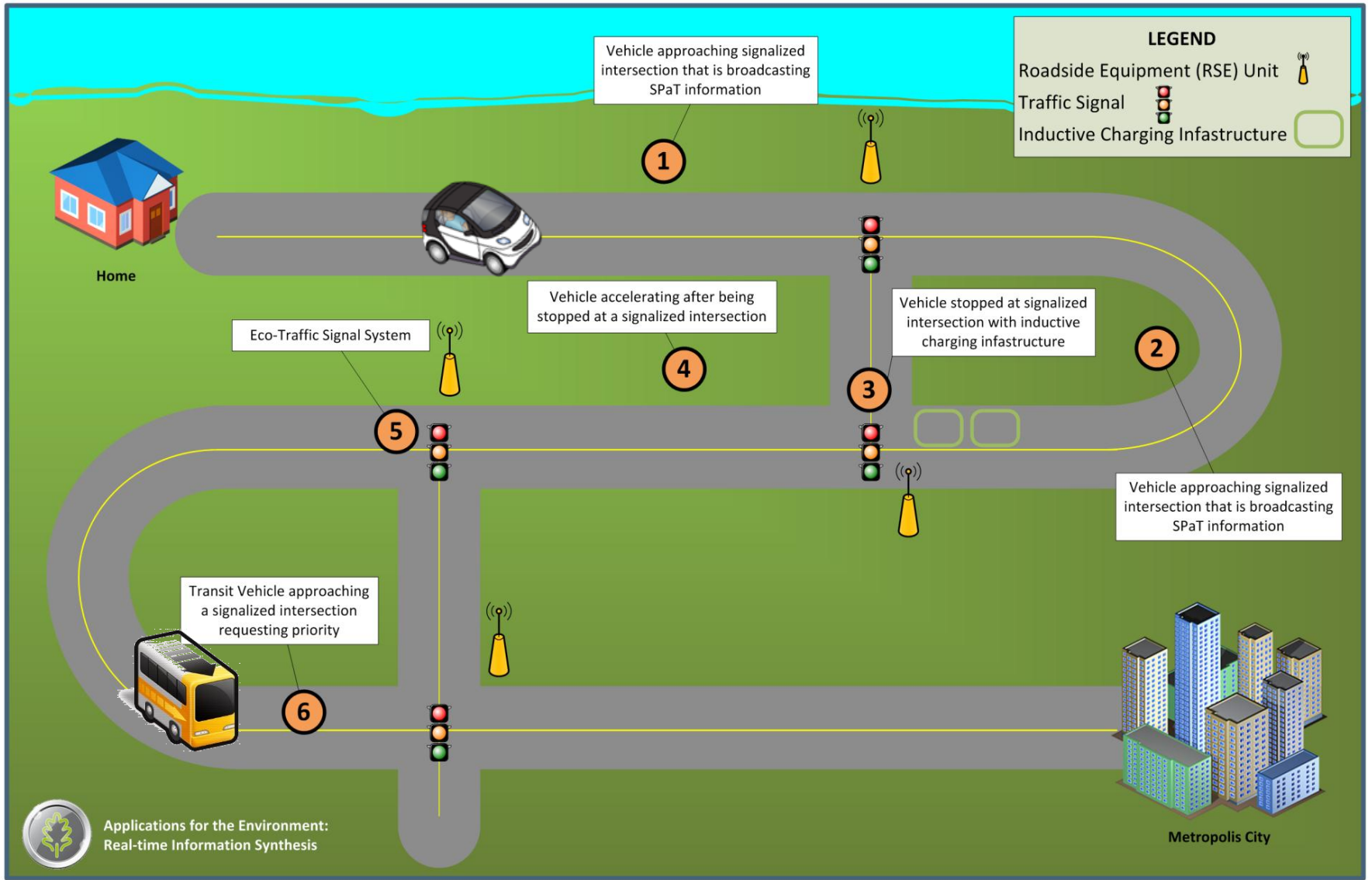
- **Similar to today's ITS:** adaptive traffic signal systems and traffic signal priority applications
- **Imagine:**
 - Signal phase and timing (SPaT) data broadcast to vehicles where in-vehicle systems perform calculations to provide speed advice to drivers in order to reduce starts, stops, idling, and to support eco-driving on arterials.
 - Adaptive traffic signal systems optimized for the environment using data collected from vehicles, such as vehicle location, speed, fuel consumption and other emissions data.
 - Inductive charging infrastructure located at stop bars enabling electric vehicles to charge while stopped at traffic signals.
 - Smarter transit signal priority based on emissions, transit vehicle occupancy, and schedule adherence data.



Eco-Signal Operations Transformative Concept

- The Eco-Signal Operations Transformative Concept includes the use of innovative applications that use connected vehicle technologies to decrease fuel consumption and decrease greenhouse gases (GHGs) and criteria air pollutant emissions on arterials by reducing idling, reducing the number of stops, reducing unnecessary vehicle accelerations and decelerations, and improving traffic flow at signalized intersections.
- The Transformative Concept includes four applications:
 - Eco-Traffic Signal Timing
 - Eco-Approach and Departure at Signalized Intersections
 - Eco-Traffic Signal Priority
 - Connected Eco-Driving

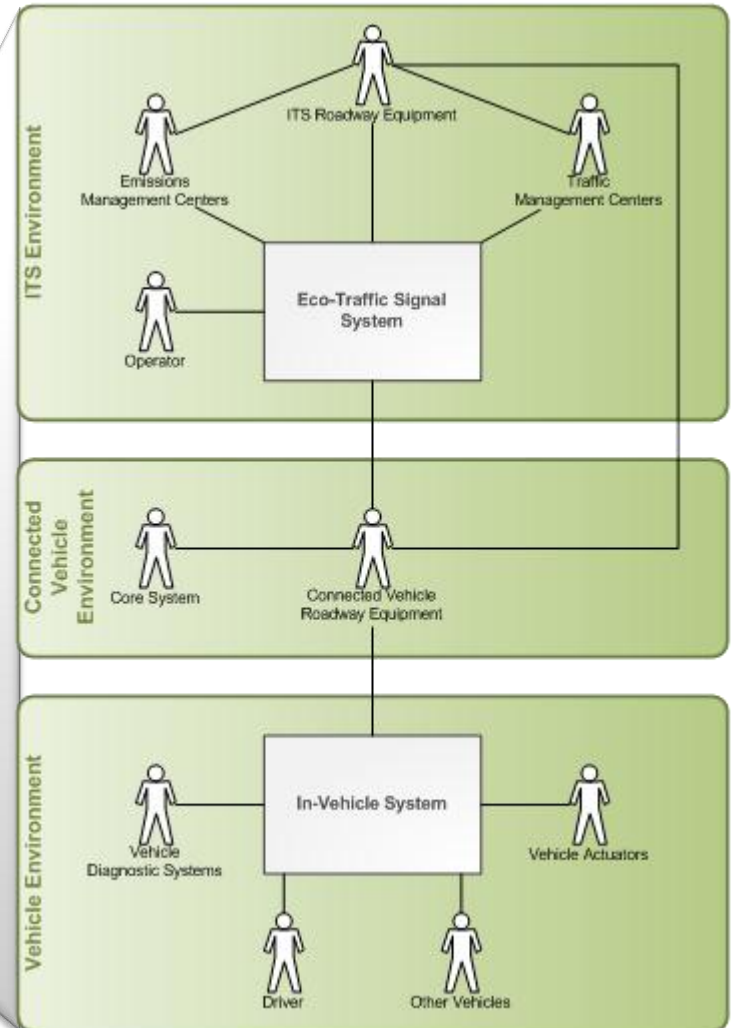
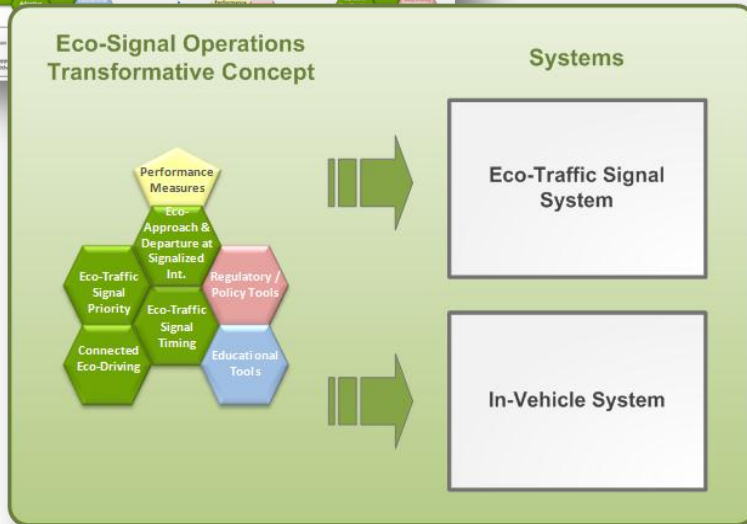
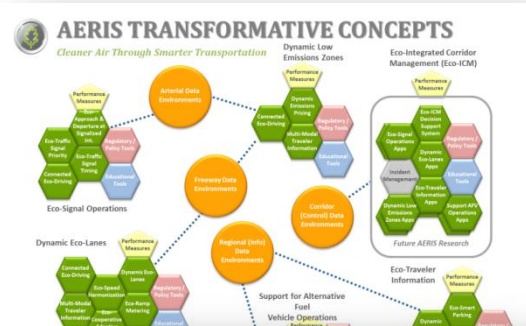




Applications for the Environment:
Real-time Information Synthesis



Eco-Signal Operations Systems

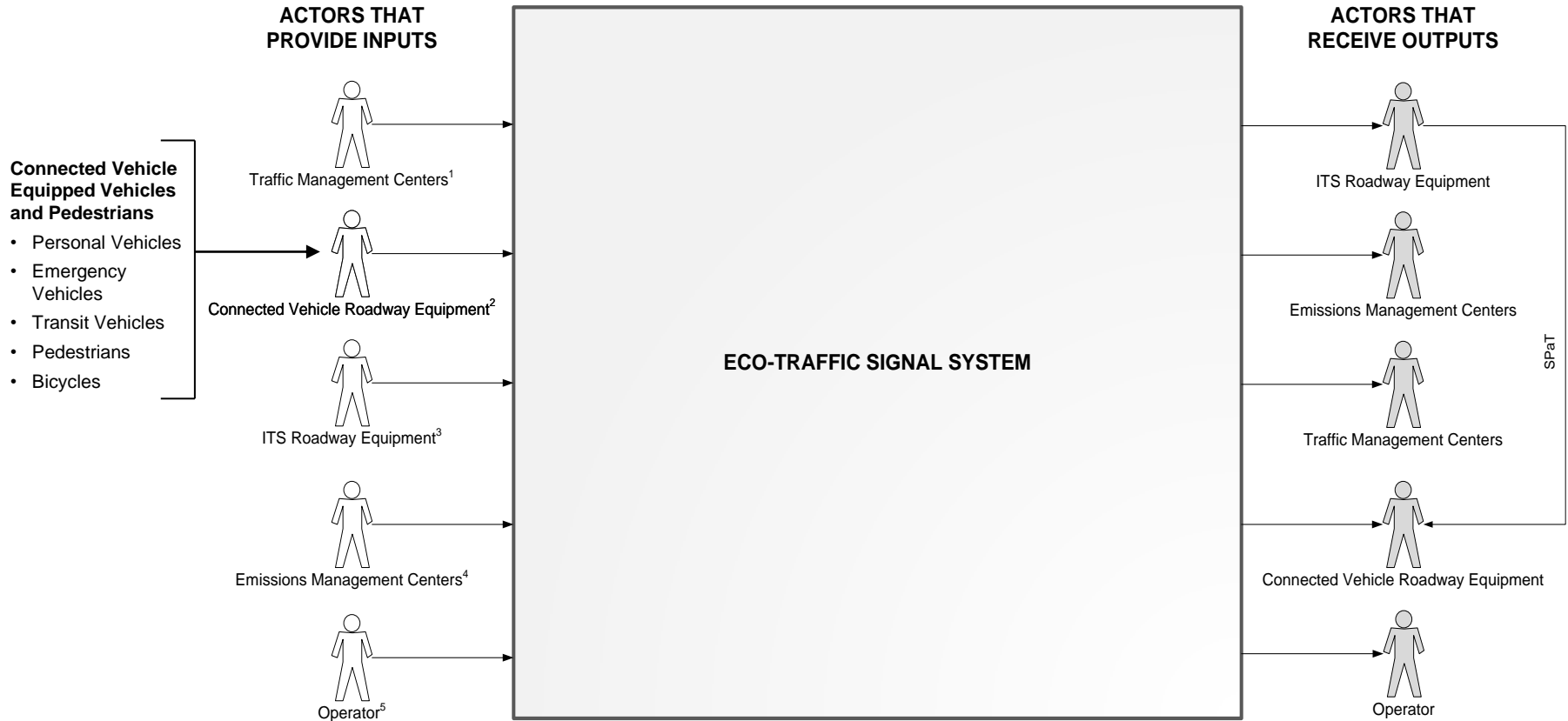


Eco-Traffic Signal System

- Similar to current traffic signal systems, but uses connected vehicle technologies to help optimize traffic signals for the environment. The system:
 1. Gathers traffic and environmental data from multiple sources including ITS Roadway Equipment, Connected Vehicle Roadway Equipment, and other systems.
 2. Processes these data to develop operational strategies at signalized intersections, focused on reducing fuel consumption and overall emissions at the intersection, along a corridor, or for a region.
 3. Evaluates traffic and environmental parameters at each intersection every cycle in real-time and adapts to fluctuating traffic and environmental conditions through its optimization algorithm.
 4. Readily adapts signal control to actual traffic volumes and environmental conditions so that the traffic network operation is optimized using available green time to serve the actual traffic demands minimizing the environmental impact.
 5. Supports eco-traffic signal priority.



Eco-Traffic Signal System

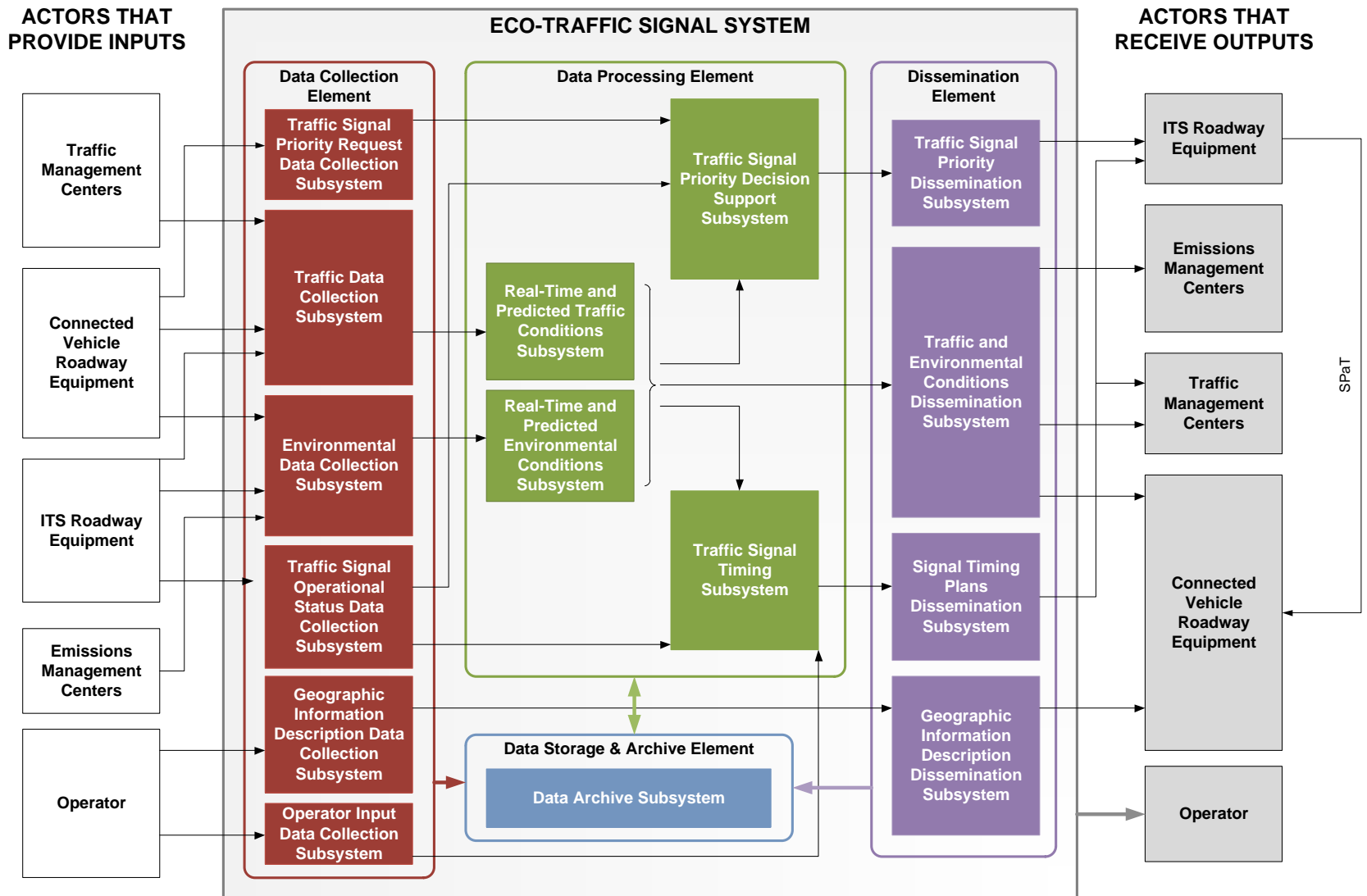


Notes:

- 1 Traffic Management Centers provide the capabilities to monitor and control traffic and the roadway network. This actor includes all systems that may reside within the Traffic Management Center.
- 2 Connected Vehicle Roadway Equipment include roadside equipment that transmit or receive data using dedicated short range communications (DSRC) radios or other wireless communications. Connected Vehicle Roadway Equipment provide data to centers (e.g., Traffic Management Centers, Emissions Management Centers) and to vehicle systems.
- 3 ITS Roadway Equipment include roadway traffic sensors, environmental sensor stations, closed circuit television (CCTV) cameras, and other ITS equipment. Traffic signal equipment (e.g., traffic signal controllers) located in the field are also included.
- 4 Emissions Management Centers provide the capabilities to monitor and manage air quality. This actor includes all systems that may reside within the Emissions Management Center.
- 5 The Operator represents the human entity that directly interfaces with the system.



Eco-Traffic Signal System *(cont'd)*



Eco-Traffic Signal System | Data Collection Needs

ID	TITLE	DESCRIPTION
ETSOS-DC-01	Collect Traffic Signal Priority Requests	The Eco-Traffic Signal System needs to collect traffic signal priority requests originating from transit vehicles and commercial vehicles equipped with traffic signal priority applications and transponders.
ETSOS-DC-02	Collect Traffic Data	The Eco-Traffic Signal System needs to collect traffic data (e.g., volume, speed, occupancy, vehicle classification, turning movements, incidents, pedestrian calls or presence at traffic signals, vehicle type, and vehicle position).
ETSOS-DC-03	Collect Environmental Data	The Eco-Traffic Signal System needs to collect environmental data (e.g. ambient air quality, emissions, temperature, wind speed, and other road weather information).
ETSOS-DC-04	Collect Traffic Signal Operational Status Data	The Eco-Traffic Signal System needs to collect data on the operational status of traffic signal equipment (e.g., traffic signal controller) including the current timing in operation.
ETSOS-DC-05	Collect Geographic Information Description Data	The Eco-Traffic Signal System needs to collect descriptions about the static physical geometry at intersections and arterial roadway segments.
ETSOS-DC-06	Collect Operator Input	The Eco-Traffic Signal System needs to collect data entered by personnel operating the system.

Eco-Traffic Signal System | Data Processing Needs

ID	TITLE	DESCRIPTION
ETSOS-DP-01	Process Traffic Data	The Eco-Traffic Signal System needs to synthesize traffic data from multiple sources (e.g., fixed sensors, connected vehicle roadway equipment, other centers) to provide traffic analyses aggregated at different levels (e.g., intersection, corridor, and regional levels).
ETSOS-DP-02	Generate Predicted Traffic Conditions	The Eco-Traffic Signal System needs to use historical and processed traffic data to predict traffic conditions aggregated at different levels (e.g., intersection, corridor, and regional levels).
ETSOS-DP-03	Process Environmental Data	The Eco-Traffic Signal System needs to synthesize environmental data from multiple sources (e.g., fixed sensors, connected vehicle roadside equipment, and other centers) to provide emissions analyses aggregated at different levels (e.g., intersection, corridor, and regional levels).
ETSOS-DP-04	Generate Predicted Emissions Profile	The Eco-Traffic Signal System needs to synthesize environmental data from multiple sources (e.g., sensors, connected vehicle roadside equipment, and other centers) to generate predicted emissions aggregated at different levels (e.g., intersection, corridor, and regional levels).
ETSOS-DP-05	Provide Traffic Signal Priority Decision Support Capabilities	The Eco-Traffic Signal System needs to include decision support capabilities for determining whether a signal priority request should be granted.
ETSOS-DP-06	Generate Traffic Signal Timing Strategy	The Eco-Traffic Signal System needs to generate traffic signal timing plans (e.g., cycle lengths, phases, offsets and other parameters) using processed traffic data, predicted traffic data, and environmental data.

Eco-Traffic Signal System | Dissemination Needs

ID	TITLE	DESCRIPTION
ETSOS-D-01	Disseminate Traffic Signal Priority Data	The Eco-Traffic Signal System needs to provide traffic signal priority action data (e.g., time to extend the green or advance the green for priority) to the traffic signal controller.
ETSOS-D-02	Disseminate Traffic Information to Other Centers	The Eco-Traffic Signal System needs to disseminate traffic data and traffic signal timing plans to other jurisdictions to enable coordination of timing plans and other operational strategies for a corridor or a region.
ETSOS-D-03	Disseminate Traffic Conditions to Vehicles	The Eco-Traffic Signal System needs to provide traffic condition messages to vehicles whose applications may consider these data when making recommendations to the driver about the vehicle's departure from a traffic signal.
ETSOS-D-04	Disseminate Environmental Conditions to Other Centers	The Eco-Traffic Signal System needs to disseminate environmental data (e.g., regional and/or local air quality, temperature, precipitation) to other centers.
ETSOS-D-05	Disseminate Environmental Conditions to Vehicles	The Eco-Traffic Signal System needs to provide environmental conditions messages to vehicles.
ETSOS-D-06	Disseminate Traffic Signal Timing Plans	The Eco-Traffic Signal System needs to provide traffic signal timing plans (e.g., cycle lengths, phases, offsets and other parameters) to the traffic signal controller.
ETSOS-D-07	Disseminate GID Messages	The Eco-Traffic Signal System needs to disseminate descriptions about the static physical geometry at intersections and arterial roadway segments.

Eco-Traffic Signal System | Storage and Archive

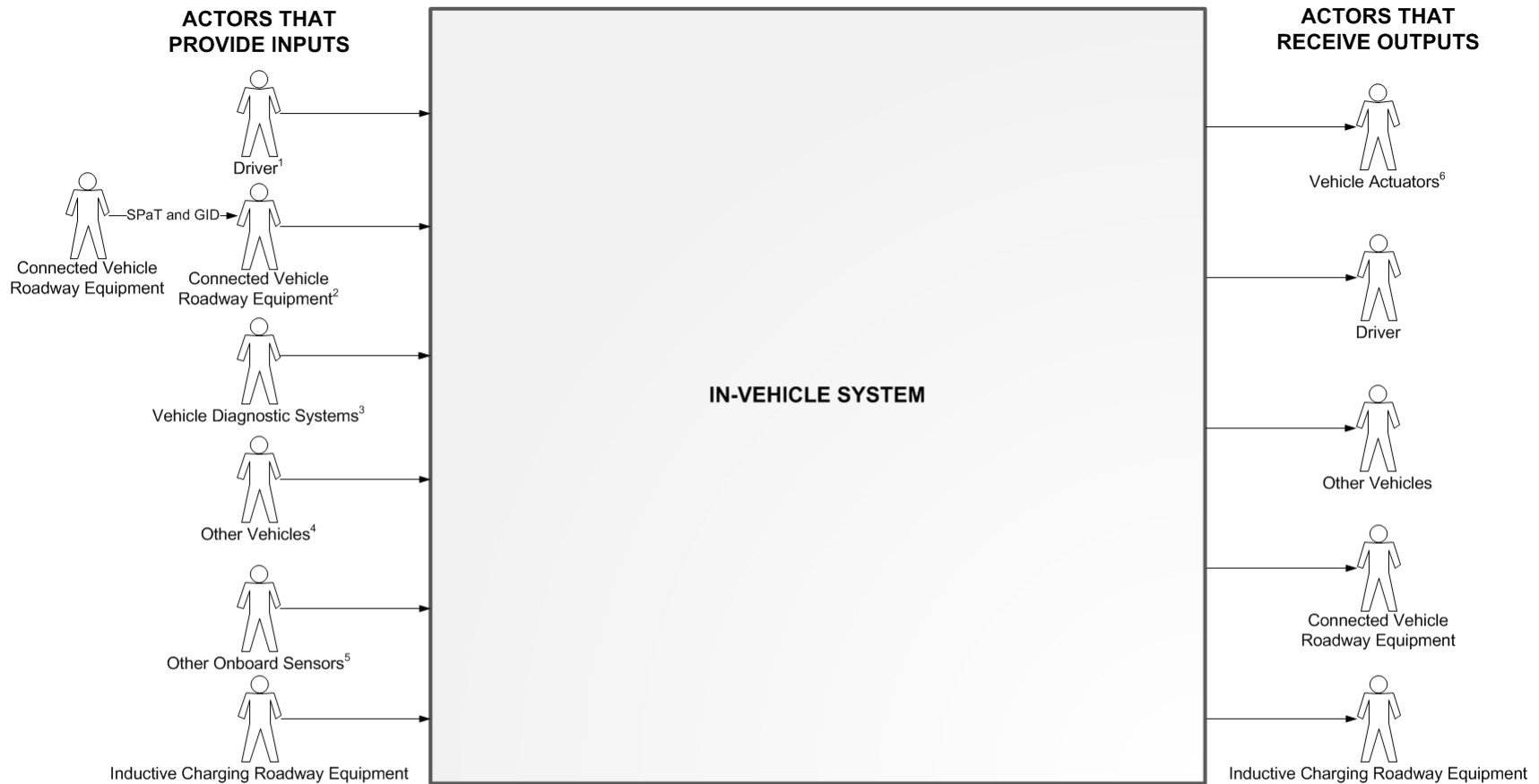
ID	TITLE	DESCRIPTION
ETSOS-DA-01	Archive Data	The Eco-Traffic Signal System needs to archive traffic data, environmental data, operations data (e.g., status of traffic signals), and event logs (e.g., signal priority requests).
ETSOS-DA-02	Determine Performance Measures	The Eco-Traffic Signal System needs to determine performance measures and make them available to the operator.

In-Vehicle System

- Allows drivers of vehicles to opt-in to applications that provide real-time information so that they can adjust driving behavior to save fuel and reduce emissions.
- Collects traffic data, environmental data, vehicle status data from other vehicles, terrain information, and SPaT information available through DSRC or other wireless communication
- Processes data to determine optimal eco-driving strategies which in turn are disseminated to the driver through an operator interface.
- Considers start-stop capabilities that automatically shut down and restart the vehicle's engine reducing the amount of time the engine spends idling, thereby reducing fuel consumption and emissions.
- Allows for wireless charging of electric vehicle batteries.
- Provides feedback / analysis of a driver's driving behavior including fuel consumption, emissions, and financial savings for a trip.



In-Vehicle System

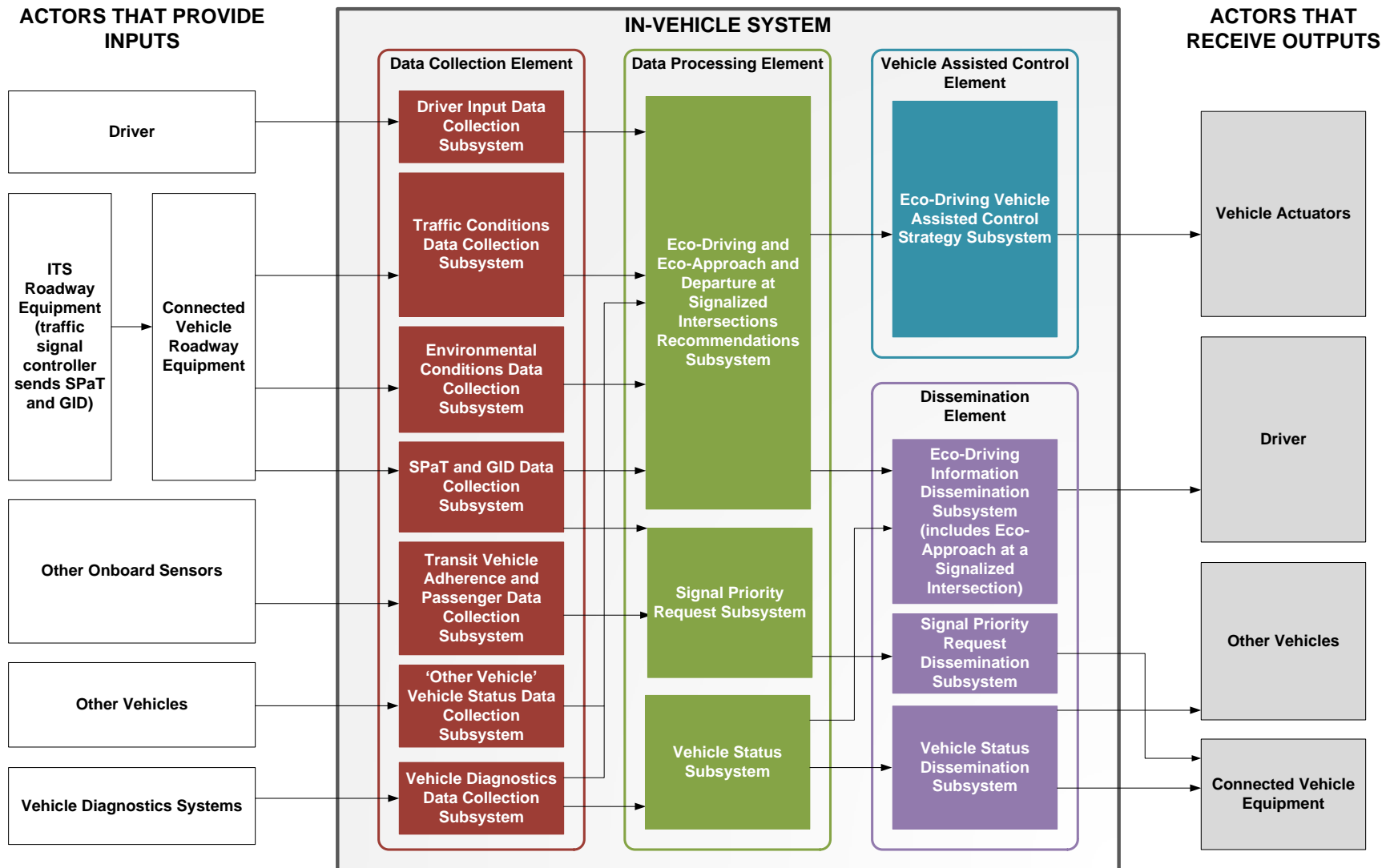


Notes:

- 1 The Driver represents the human entity that operates a licensed vehicle on the roadway. The Driver inputs information such as their origin and destination into the Eco-Driving System through a Human Machine Interface (HMI). Additionally, the Driver may turn on vehicle-assisted capabilities through the HMI.
- 2 Connected Vehicle Roadway Equipment include roadside equipment that transmit or receive data using dedicated short range communications (DSRC) radios or other wireless communications. Connected Vehicle Roadway Equipment provide data to centers (e.g., Traffic Management Centers, Emissions Management Centers) and to vehicle systems.
- 3 Vehicle Diagnostic Systems represent computer based systems, located on vehicles, designed to monitor the performance of some of the engine's major components.
- 4 Other Vehicles include passenger, commercial, and transit vehicles that are enabled with Connected Vehicle technologies.
- 5 Other On-board Sensors include sensors that may be installed on vehicles to collect traffic or environmental data. Sensors may be added to vehicles to measure atmospheric or surface conditions.
- 6 Vehicle Actuators include electromechanical devices that control different systems within the vehicle. For example, Vehicle Actuators can control the vehicle's idle speed, speed, apply the brake, or regulate the fuel metered into the system.



In-Vehicle System *(cont'd)*



In-Vehicle System | Data Collection Needs

ID	TITLE	DESCRIPTION
IVS-DC-01	Collect Driver Input	The In-Vehicle System needs to collect data from the driver to activate applications. The driver also needs to be able to configure parameters of the system or override certain system functions.
IVS-DC-02	Receive Traffic Conditions Data	The In-Vehicle System needs to receive traffic conditions data for input to eco-driving strategies.
IVS-DC-03	Receive Environmental Conditions Data	The In-Vehicle System needs to receive environmental conditions data so the system can present this information to drivers so they can make informed decisions during their trip.
IVS-DC-04	Collect Signal Phase and Timing (SPaT)	The In-Vehicle System needs to collect signal phase and timing (SPaT) data as the vehicle approaches a signalized intersection.
IVS-DC-05	Collect Geographic Information Description Data	The In-Vehicle System needs to receive Geographic Information Description (GID) data. These data includes descriptions about the static physical geometry at intersections and arterial roadway segments.
IVS-DC-06	Collect Data for Signal Priority	The In-Vehicle System needs to collect data from on-board systems about the transit vehicle's adherence to a schedule or the number of passengers.
IVS-DC-07	Receive Vehicle Status Data from Other Vehicles	The In-Vehicle System needs to collect vehicle status data from other vehicles, including data that is currently in the SAE J2735 basic safety message (BSM) (e.g., data about the vehicle's location, heading, speed, acceleration).
IVS-DC-08	Collect Vehicle Diagnostics Data	The In-Vehicle System needs to collect diagnostics data from onboard systems and onboard sensors to obtain vehicle status and vehicle emissions data.
IVS-DC-09	Receive Inductive Charge	Electric Vehicles need to receive inductive charges from wireless inductive charging pads.

In-Vehicle System | Data Processing Needs

ID	TITLE	DESCRIPTION
IVS-DP-01	Determine Eco-Driving Recommendations	The In-Vehicle System needs to determine driving recommendations with the objective of promoting a driving style that lowers vehicle emissions and fuel consumption.
IVS-DP-02	Determine Eco-Approach and Departure at Signalized Intersection	The In-Vehicle System needs to use signal phase and timing (SPaT) data, Geographic Information Description (GID) data, traffic data, vehicle sensor data, and vehicle status data from other vehicles to encourage “green” approaches to and departures from signalized intersections.
IVS-DP-03	Determine Traffic Signal Priority Request Strategy	The In-Vehicle Systems needs to use data collected from on-board systems to determine if a request needs to be made for priority at a signalized intersection.
IVS-DP-04	Determine Vehicle Emissions Data	The In-Vehicle System needs to calculate estimates of tailpipe emissions and fuel consumption if these data cannot be collected directly from the vehicle.



In-Vehicle System | Vehicle Control Needs

ID	TITLE	DESCRIPTION
IVS-VC-01	Provide Eco-Driving Vehicle Assisted Control Strategy	The In-Vehicle System needs to process and provide data to vehicle actuators to support vehicle assisted and autonomous driving vehicle controls.
IVS-VC-02	Provide Start-Stop Capabilities	The In-Vehicle System needs to provide start-stop capabilities allowing the vehicle's engine to be automatically shutting down and restarted.



In-Vehicle System | Dissemination Needs

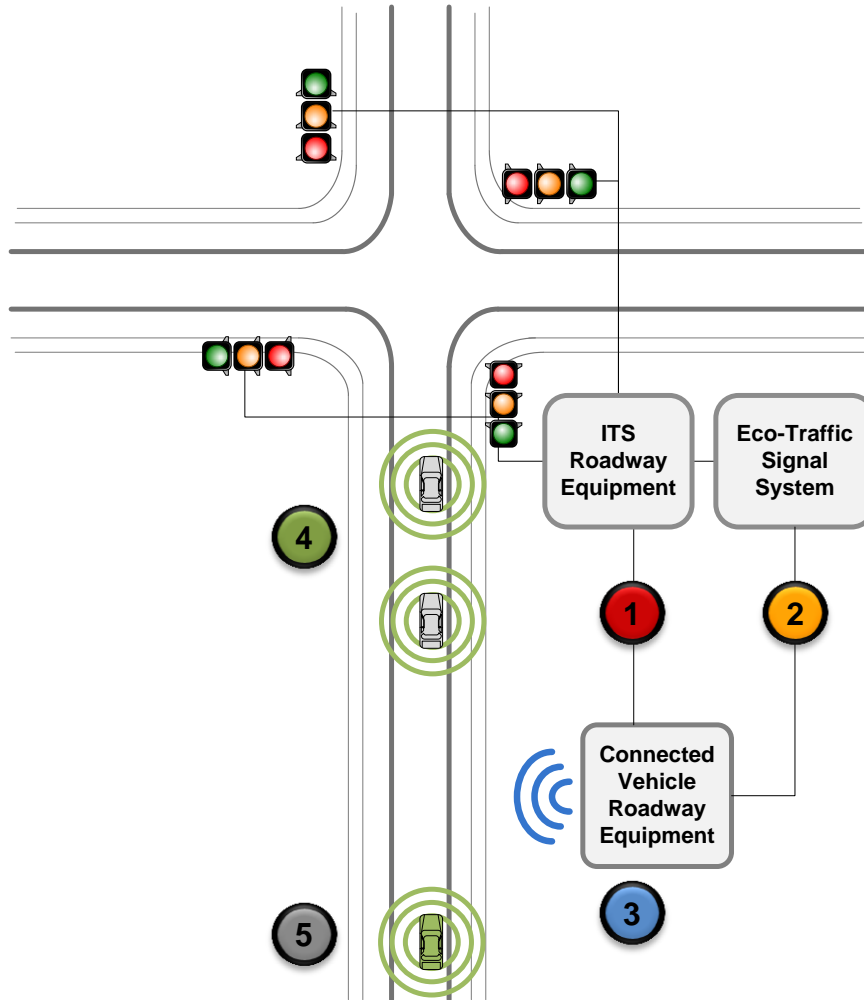
ID	TITLE	DESCRIPTION
IVS-D-01	Provide Eco-Driving Information to the Driver	The In-Vehicle System needs to provide drivers with eco-driving information that encourages them to drive in a more environmentally efficient manner.
IVS-D-02	Send Traffic Signal Priority Request	The In-Vehicle System needs to request traffic signal priority at a signalized intersection.
IVS-D-03	Disseminate Vehicle Status Data	The In-Vehicle System needs to broadcast vehicle status data or data that is currently included in the SAE J2735 basic safety message (BSM) (e.g., data about the vehicle's location, heading, speed, acceleration, braking status, and size).
IVS-D-04	Disseminate Vehicle Status Environmental Data	The In-Vehicle System needs to broadcast environmental data messages based on data collected from sensors located on-board the vehicle, or data that it processed.



5. SCENARIOS



Eco-Approach and Departure at Signalized Intersections

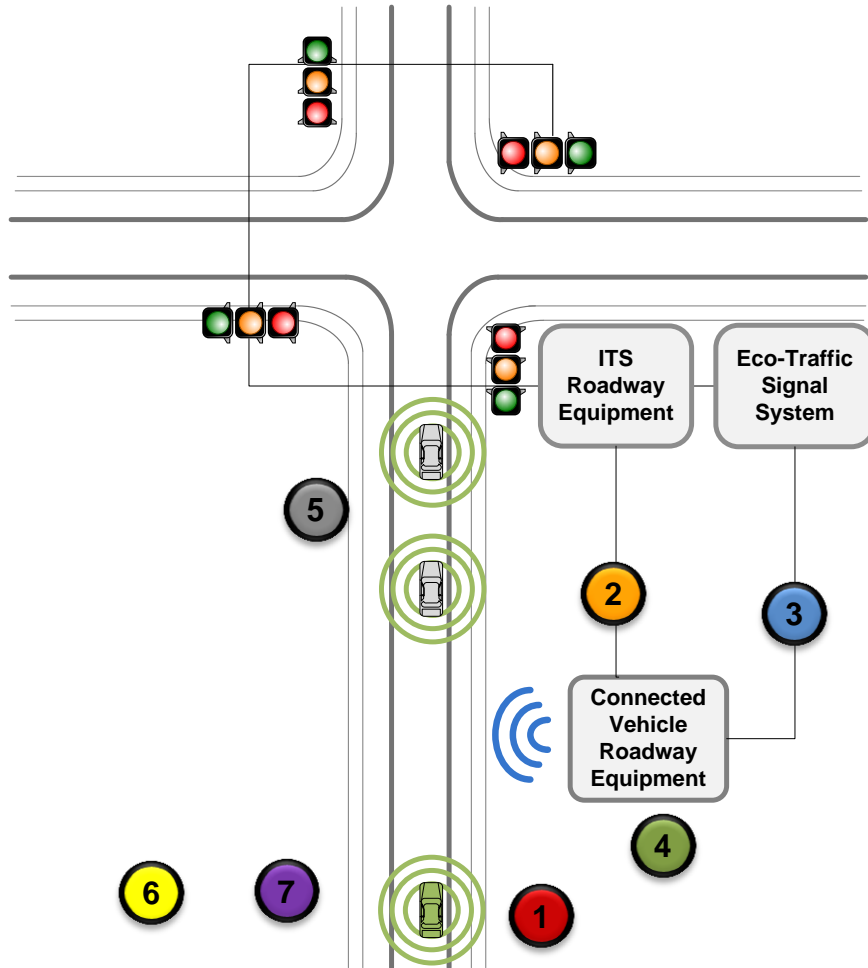


DRAWING NOT TO SCALE

Step	Description
1	The traffic signal controller sends the traffic signal's current SPaT data to the Connected Vehicle Roadway Equipment. Which converts the data to a SAE J2735 SPaT message.
2	The Eco-Traffic Signal System sends traffic conditions data to the Connected Vehicle Roadway Equipment, including average speeds, queues at the stop bar, and incidents along the roadway. The Eco-Traffic Signal System also sends GIDs to the Connected Vehicle Roadway Equipment describing the static physical geometry of one or more intersections.
3	The Connected Vehicle Roadway Equipment broadcasts SPaT, GID, and traffic condition messages. SPaT messages are broadcasted 10 times per second.
4	Other Vehicles broadcast vehicle status messages including the vehicle's location, motion (e.g., heading and acceleration), braking status, size, and vehicle type.
5	The In-Vehicle System collects data and determines the vehicle's optimal trajectory (e.g., speed, acceleration, and braking) as the vehicle approaches or departs from the signalized intersection. <ul style="list-style-type: none">• The application first attempts to identify a speed for the vehicle to traverse the intersection during a green light.• If the application determines that the vehicle cannot traverse the intersection on a green light, it determines a strategy for the vehicle to decelerate to the intersection in the most environmentally efficient manner.• If the vehicle is stopped or slows down, the application will recommend the most environmentally efficient acceleration as the vehicle departs from the intersection.• Finally if stopped, the application automatically shuts down and restarts the vehicle's engine reducing the amount of time the engine spends idling, thereby reducing fuel consumption and emissions.



Eco-Approach and Departure at Signalized Intersections – Autonomous Control

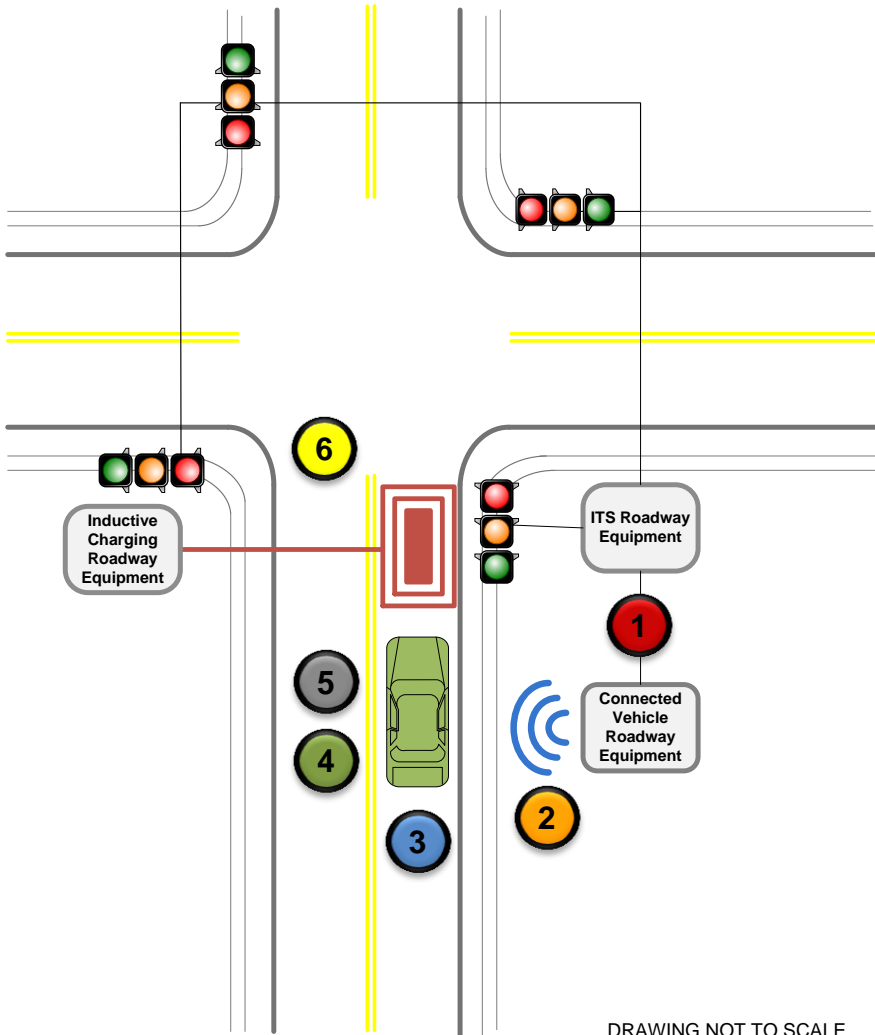


DRAWING NOT TO SCALE

Step	Description
1	A vehicle is equipped with an eco-driving application which also includes a feature allowing for automated control of the vehicle (e.g., the feature controls the speed and acceleration of the vehicle, but still requires the driver to steer the vehicle). The driver turns on the application and the automated driving capability using a human machine interface (HMI) in the vehicle.
2	The traffic signal controller sends the traffic signal's current SPaT data to the Connected Vehicle Roadway Equipment. The data is converted into a SAE J2735 SPaT message.
3	The Eco-Traffic Signal System sends traffic conditions and GIDs to the Connected Vehicle Roadway Equipment describing the static physical geometry of one or more intersections.
4	The Connected Vehicle Roadway Equipment broadcasts SPaT, GID, and traffic condition messages. SPaT messages are broadcasted 10 times per second.
5	Other Vehicles broadcast vehicle status messages including the vehicle's location, motion (e.g., heading and acceleration), braking status, size, and vehicle type.
6	The In-Vehicle System collects data and determines the vehicle's optimal trajectory (e.g., speed, acceleration, and braking) as the vehicle approaches or departs from the signalized intersection.
7	Once eco-driving recommendations are determined by the application, data is sent to vehicle actuators which adjust the speed, accelerations/decelerations, and braking of the vehicle. The driver maintains control of the steering of the vehicle. Data collected from other vehicles using vehicle-to-vehicle (V2V) communications are considered to ensure that the vehicle does not collide with other vehicles.



Inductive Charging at Signalized Intersections



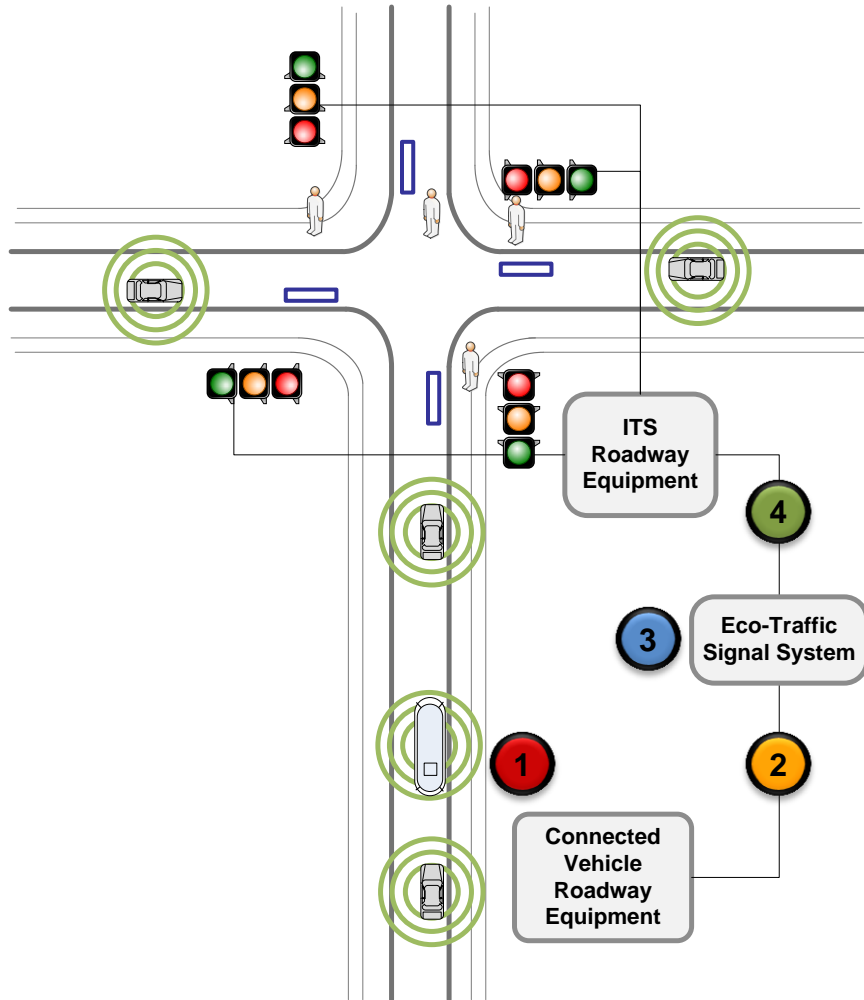
DRAWING NOT TO SCALE

Step	Description
1	The traffic signal controller sends the traffic signal's current SPaT data to the Connected Vehicle Roadway Equipment. The data is converted into a SAE J2735 SPaT message.
2	The Connected Vehicle Roadway Equipment broadcasts SPaT and GID messages. The GID message includes the locations of inductive charging infrastructure near signalized intersections.
3	The In-Vehicle System receives SPaT and GID messages – including the location of inductive charging infrastructure. The driver of the electric vehicle opts into an inductive charging application. The application informs the driver of the location of inductive charging infrastructure.
4	As the vehicle approaches the inductive charging pad at a red light, the vehicle establishes a wireless connection with the inductive charging infrastructure. A handshake process begins, payment information sent to inductive charging equipment, and electric charge is transferred from the pad to the vehicle.
5	The In-Vehicle System continues to receive SPaT messages as it sits at the red light. Five seconds before the traffic signal turns green, the charge terminates.
6	The traffic signal turns green and the vehicle accelerates away from the intersection. The In-Vehicle System notifies the driver about the vehicle's charge level.





Eco-Traffic Signal Timing



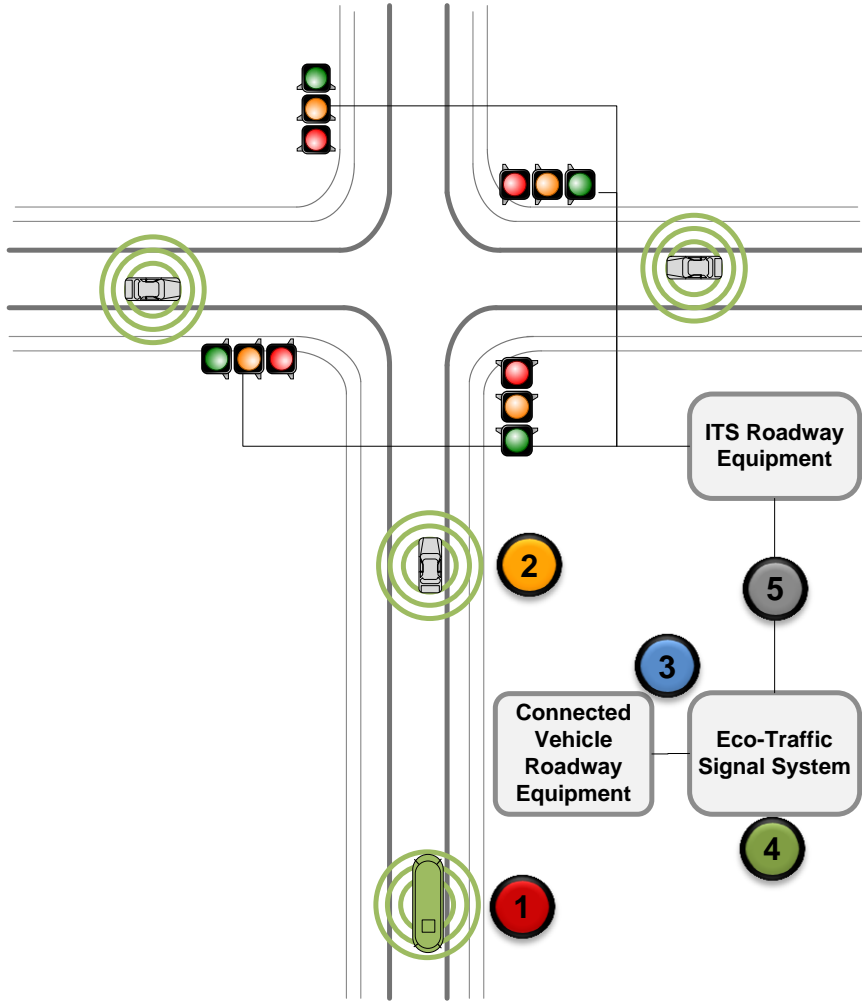
DRAWING NOT TO SCALE

Step	Description
1	Vehicles send vehicle status data to the Connected Vehicle Roadway Equipment. Vehicle status data includes data about the vehicle's location, motion (e.g., heading and acceleration), braking status, size, and vehicle type as well as environmental status data such as the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption.
2	The Connected Vehicle Roadway Equipment sends the vehicle status data to the Eco-Traffic Signal System.
3	The Eco-Traffic Signal System processes the vehicle status data to develop real-time and predicted traffic and environmental conditions for the roadway segment. Together the traffic and environmental data are used to generate eco-traffic signal timing plans (e.g., cycle lengths, phases, offsets and other parameters). This may include fixed timing plans based on the time of day or capabilities similar to current adaptive traffic control systems; however, the objective should be to generate signal timing plans to minimize the environmental impact of traffic at a single intersection, along a corridor, or a region, and to select the appropriate traffic signal timing strategy to be implemented.
4	The Eco-Traffic Signal System sends the traffic signal timing plans to the ITS Roadway Equipment (i.e., traffic signal controller) which implements the signal timing plan.





Eco-Traffic Signal Priority



DRAWING NOT TO SCALE

Step	Description
1	The Transit Vehicle sends a request for signal priority to the Connected Vehicle Roadway Equipment. In addition to the signal priority request, the transit vehicle also collects and transmits data from on-board systems including the number of passengers on the transit vehicle and the transit vehicle's adherence to its schedule.
2	Vehicles in the vicinity of the signalized intersection send vehicle status data to the Connected Vehicle Roadway Equipment. Vehicle status data includes the vehicle's location, motion (e.g., heading and acceleration), braking status, size, and vehicle type as well as the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption.
3	The Connected Vehicle Roadway Equipment sends the vehicle status data to the Eco-Traffic Signal System. The Connected Vehicle Roadway Equipment also sends the Transit Vehicle's signal priority request.
4	Upon receiving the signal priority request from the Transit Vehicle, the Eco-Traffic Signal System uses the traffic and environmental conditions data to determine if signal priority should be granted. The Eco-Traffic Signal Priority application considers the current state of the traffic signal, traffic volumes for all approaches to the traffic signal, vehicle emissions from vehicles at all approaches to the traffic signal, traffic conditions downstream of the intersection, the number of passengers on the transit vehicle, and the transit vehicle's adherence to its schedule.
5	If it is determined that signal priority should be granted, the Eco-Traffic Signal System sends the request for signal priority to the ITS Roadway Equipment which implements the traffic signal control strategy (i.e., signal priority).

6. GOALS, OBJECTIVES, AND PERFORMANCE MEASURES



Goals, Objectives, and Performance Measures

Goal #1: Reduce Environmental Impacts	Goal #2: Support “Green Transportation Decisions” by Travelers and Operating Entities	Goal #3: Enhance Mobility of the Transportation System (secondary goal)	Goal #4: Improve the Safety of the Transportation System (secondary goal)
<ul style="list-style-type: none"> • Reduce Emissions from Surface Transportation Vehicles <ul style="list-style-type: none"> • Reduce CO₂, CO, NO_x, SO₂, PM₁₀, PM_{2.5}, VOCs • Reduce Energy Consumption Associated with Surface Transportation Vehicles <ul style="list-style-type: none"> • Reduce excess fuel • Reduce energy consumption 	<ul style="list-style-type: none"> • Increase Eco-Driving Awareness and Practice <ul style="list-style-type: none"> • Increase the numbers of drivers practicing eco-driving strategies • Increase the number of eco-driving marketing/outreach activities • Reduce Range Anxiety for Drivers Driving Electric Vehicles <ul style="list-style-type: none"> • Reduce Drivers fear of Range Anxiety • Increase the Range of Electric Vehicles <ul style="list-style-type: none"> • Increase the distance that electric vehicles can travel without stopping at a charging station 	<ul style="list-style-type: none"> • Improve the Efficiency of the Transportation System <ul style="list-style-type: none"> • Reduce delay per person • Decrease control delay per vehicle on arterials • Increase miles of arterials operating at LOS ‘X’ • Improve Transit Operating Efficiency <ul style="list-style-type: none"> • Reduce transit travel times • Decrease signal delay on transit routes • Increase the implementation of transit signal priority • Improve Freight Operating Efficiency <ul style="list-style-type: none"> • Reduce delay on freight-significant routes • Increase customer satisfaction 	<ul style="list-style-type: none"> • Reduce Crashes, Injuries, and Fatalities on Arterials <ul style="list-style-type: none"> • Reduce crashes, injuries, and fatalities at signalized intersections • Reduce secondary crashes, injuries, and fatalities at signalized intersections • Reduce crashes, injuries, and fatalities due to red-light running • Reduce crashes, injuries, and fatalities due to adverse road weather conditions • Reduce crashes, injuries, and fatalities at railroad crossings



Next Steps

- The AERIS Program wants to hear your thoughts on the Eco-Signal Operations Transformative Concept.
 - You can provide inputs and feedback using the AERIS IdeaScale Site (www.aeris.ideascale.com).
 - The AERIS Program will be conducting a Workshop in early 2013 to walk-through the Concept of Operations for the Eco-Signal Operations Transformative Concept and other AERIS ConOps. More details will be provided as workshop planning is finalized.





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