UNITED STATES
DEPARTMENT OF TRANSPORTATION

Dynamic Eco-Lanes
Concept of Operations (ConOps)

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

Fall/Winter Webinar Series

February 13th, 2013

Presentation Overview

1. Background and Description of Current Situation
2. Dynamic Eco-Lanes Transformative Concept
3. Scenarios
4. Goals, Objectives, and Performance Measures

Dynamic Eco-Lanes

- **Similar to today's ITS:** high occupancy vehicle (HOV) lanes

- **Imagine tomorrow's connected vehicle:**
  - Dedicated eco-lanes on freeways optimized for the environment that encourage use by low emission, high occupancy, freight, transit, and alternative fuel or regular vehicles operating in eco-friendly ways.
  - Eco-speed limits optimized for the environment based on data collected from vehicles. Eco-speed limits would be implemented to help to reduce unnecessary vehicle stops and starts by maintaining consistent speeds, thus reducing GHG and other emissions.
  - Cooperative eco-adaptive cruise control (CACC) applications where individual drivers may elect to opt-into applications that provide cruise control capabilities designed to minimize vehicle accelerations and decelerations for the benefit of reducing fuel consumption and vehicle emissions.
  - Inductive charging infrastructure that charges electric vehicles moving at highway speeds.

The Dynamic Eco-Lanes ConOps

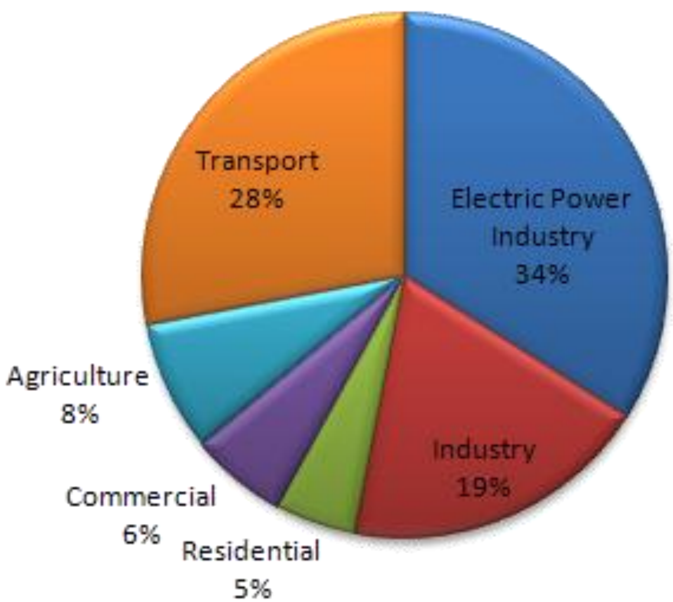
- Provides an operational description of “how” the Transformative Concept may operate.
- Communicates user needs and desired capabilities for and expectations of the Dynamic Eco-Lanes Transformative Concept .
- Builds consensus among AERIS user groups and stakeholders concerning these needs and expectations.
  - 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.

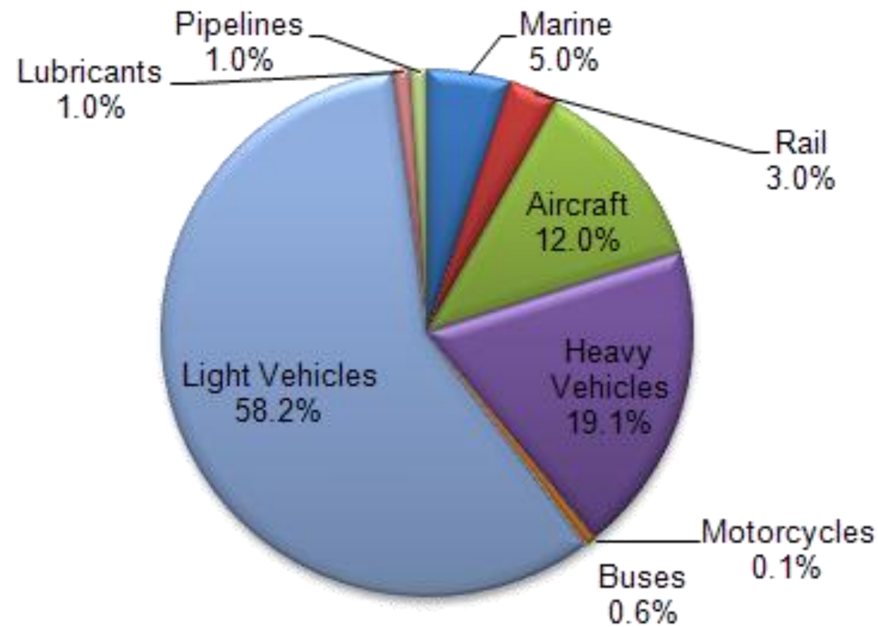
1. BACKGROUND AND DESCRIPTION OF CURRENT SITUATION

Why Is the Environment a Part of Connected Vehicle Research?

Surface transportation has a significant impact on the environment:

- Transport sector accounts for 28% of GHG emissions in the US.
- Surface vehicles represent almost 80% of the transport sector GHG in the US.





Source: EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 to 2006.* 2008.

Strategies for Reducing Surface Transportation-Related Emissions

Strategy #1 Vehicle Technology

- Improve the energy efficiency of the vehicle fleet by implementing more advanced technologies (e.g., aerodynamics, weight, engine efficiency)

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

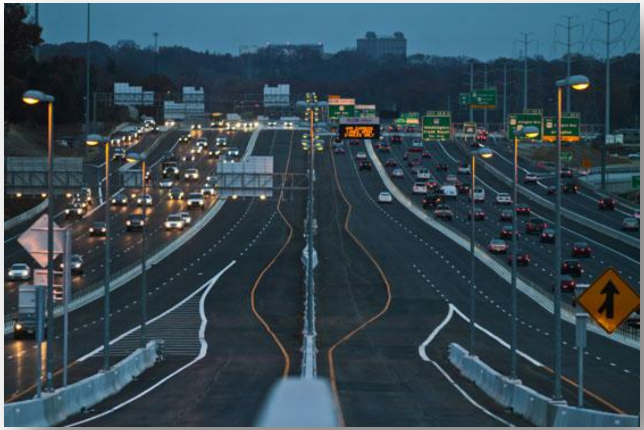
Strategy #4 Vehicle and System Operations

- 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

High-Occupancy Vehicle (HOV) and High-Occupancy Toll (HOT) Lanes

- **HOV Lanes**
  - Restricted traffic lanes, reserved at peak travel times (or longer) for exclusive use of vehicles with a driver and one or more passengers.
  - Increase average vehicle occupancy and person throughput.
  - Improve traffic flow, reducing car trips, and thus reduce vehicular emissions.
  - Some jurisdictions **exempt low emission and green vehicles (e.g., hybrid vehicles).**

- **HOT Lanes or Express Lanes**
  - Capitalize on unused capacity in HOV lanes by providing motorists in single-occupant vehicles access to HOV lanes.
  - Pricing schemes are established to minimize traffic congestion on the HOT lanes.
  - Collect fee using open roll tolling (ORT) technologies.



Source: The Washington Post
http://www.washingtonpost.com/blogs/dr-gridlock/wp/2012/11/19/495-express-lanes-open-for-first-rush-hour

Source: My FOXdc
http://www.myfoxdc.com/story/20133760/caution-urged-for-rush-hour-with-new-express-lanes#axzz2IFRtSHu8

Variable Speed Limit (VSL) Systems and Speed Reductions

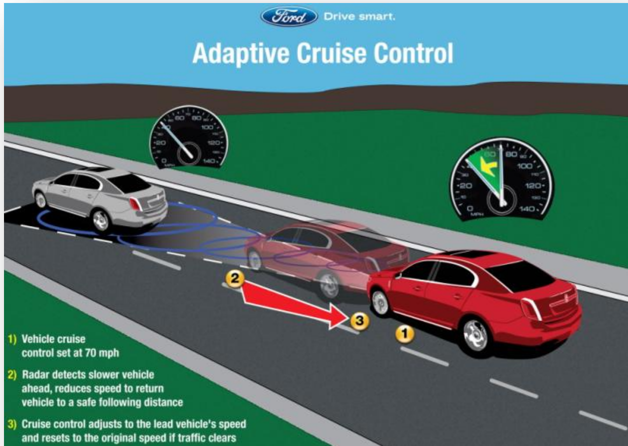
- **Variable Sped Limit (VSL) Systems**
  - Collect traffic data using traffic sensors and post speed limits that harmonize traffic flow using dynamic speed signs.
  - Account for traffic conditions, weather conditions, time of day, traffic incidents and lane closures.
  - Reduce congestion, provide more reliable journey times, reduce the frequency of accidents, reduce carbon emissions, and reduce driver stress.

- **Speed Reductions**
  - Research from the University of Texas at Austin found that reducing speed limits on a freeway from 65 mph to 55 mph on a “Code Red Air Quality Day” resulted in a 17% reduction in NO_x over a 24 hour period.
  - Graz, the second largest city in Austria, reduced speed limits from 50 kph (31 mph) to 30 kph (19 mph) for the entire city area. During the two-year trial, NO_x emissions were reduced by 25%.

Source: The A14 Alternative
http://a14alternative.com

Source: FHWA Office of International Program
http://international.fhwa.dot.gov/pubs/pl07012/atm_eu07_02.cfm

Adaptive Cruise Control and Vehicle Platooning



Source: Ford

Source: Top News (UK)

Environmental Benefits of ACC:

- The Netherlands: ACC reduced CO_2 and NO_x by 3%.[1]
- Southeast Michigan: ACC tests with 108 non-professional drivers reduced fuel consumption by 10% compared to manual driving.[2]
- California: An ACC simulation between Palo Alto and San Jose reduced fuel consumption by 5% to 7%.[2]

Environmental Benefits of Vehicle Platooning:

- Volvo demonstrated vehicle platooning- a new technology that lets driverless cars sync up with a leading vehicle.
- A demonstration was conducted in Gothenburg, Sweden as part of the European Union's research project, known as SARTRE (Safe Road Trains for the Environment).
- Vehicle platooning **is expected to slash motorway CO_2 emissions by up to 20%.**[3]

1. Mahmod, M., van Arem, B., Pueboobpaphan, R., & Igamberdiev, M. (2009). Modeling reduced traffic emissions in urban areas: the impact of demand control, banning heavy duty vehicles, speed restriction and adaptive cruise control. TRB 2010 Annual Meeting. Washington, DC: TRB.
2. National Research Council. (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.* Washington, DC: The National Academies Press.
3. Top News (UK). http://topnews.co.uk/217706-platooning-can-slash-road-co2-emissions-20-cent

Electric Vehicle Charging

Catenary Systems

Source: Siemens eHighway
http://www.mobility.siemens.com/

- Heavy goods vehicles (HGVs) draw electric energy from a catenary system using an adaptive pantograph to establish contact with the overhead wire.
- Wherever there is no overhead line, the HGVs switch over to their diesel-hybrid drive system.
- Systems are being investigated for the I-710 Corridor in Southern California.

Inductive Charging

Source: Federal Transit Administration (FTA)

- Inductive charging uses an electromagnetic field to transfer energy between two objects,
- Energy is sent through an inductive coupling to an electrical device, which can use the energy to charge batteries or run the device.
- FTA Demonstration Sites:
  - Howard County Maryland
  - CARTA – Chattanooga
  - McAllen, Texas: 3 bus stops
  - University of Utah Campus Shuttle: 3 bus stops

2. DYNAMIC ECO-LANES TRANSFORMATIVE CONCEPT

Dynamic Eco-Lanes

- The Dynamic Eco-Lanes:
  - Feature dedicated lanes optimized for the environment, referred to as eco-lanes. Eco-lanes are similar to high-occupancy vehicle (HOV) lanes and are optimized for the environment through the use of connected vehicle data.
  - Target low-emission, high-occupancy, freight, transit, and alternative-fuel vehicles (AFV).
  - Allow drivers to take advantage of eco-friendly applications such as eco-cooperative adaptive cruise control (CACC) and vehicle platooning.
  - Include variable speed limits optimized for the environment – referred to as eco-speed limits.
  - Support the operation of dynamic eco-lanes, including establishing criteria for entering the lanes and defining or geo-fencing the eco-lane boundaries, allowing the lanes to be dynamic.
  - Include inductive charging capabilities for electric vehicles.

Dynamic Eco-Lanes

- Eco-Lanes may:
  - Be implemented on **arterials or freeways**.
  - Consider dynamic parameters:
    - Location of the lanes
    - Number of lanes (e.g., single lane or multiple lanes)
    - Types of vehicles allowed to use the lanes
      - Open to all vehicles
      - Restricted to low emission vehicles
      - Truck-only lanes
      - Transit-only lanes
    - Various operational strategies
      - Eco-speed limits
      - Vehicle platooning

Potential Variations of Eco-Lanes

Parameters for Electric Vehicle or AFV Lanes

Source: Nissan
http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/eco_town.html

Parameters for Dedicated Truck-Only Lanes

Source: The Atlantic Cities
http://www.theatlanticcities.com/technology/2012/05/coming-soon-l-dedicated-electric-lanes-trucking/2016/

Potential Variations of Eco-Lanes *(cont'd)*

Parameters for Bus-Only Lanes

Source: Energy, Climate, Transportation Blogspot
http://energyclimatetransportation.blogspot.com/2011/06/high-occupancy-vehicle-and-bus-lanes.html#!/2011/06/high-occupancy-vehicle-and-bus-lanes.html

Parameters for Vehicle Platoon Lanes

Source: PATH
http://www.path.berkeley.edu/PATH/Research/Demos/

Defining the System and Actors

DYNAMIC ECO-LANES SYSTEM

Dynamic Eco-Lanes System

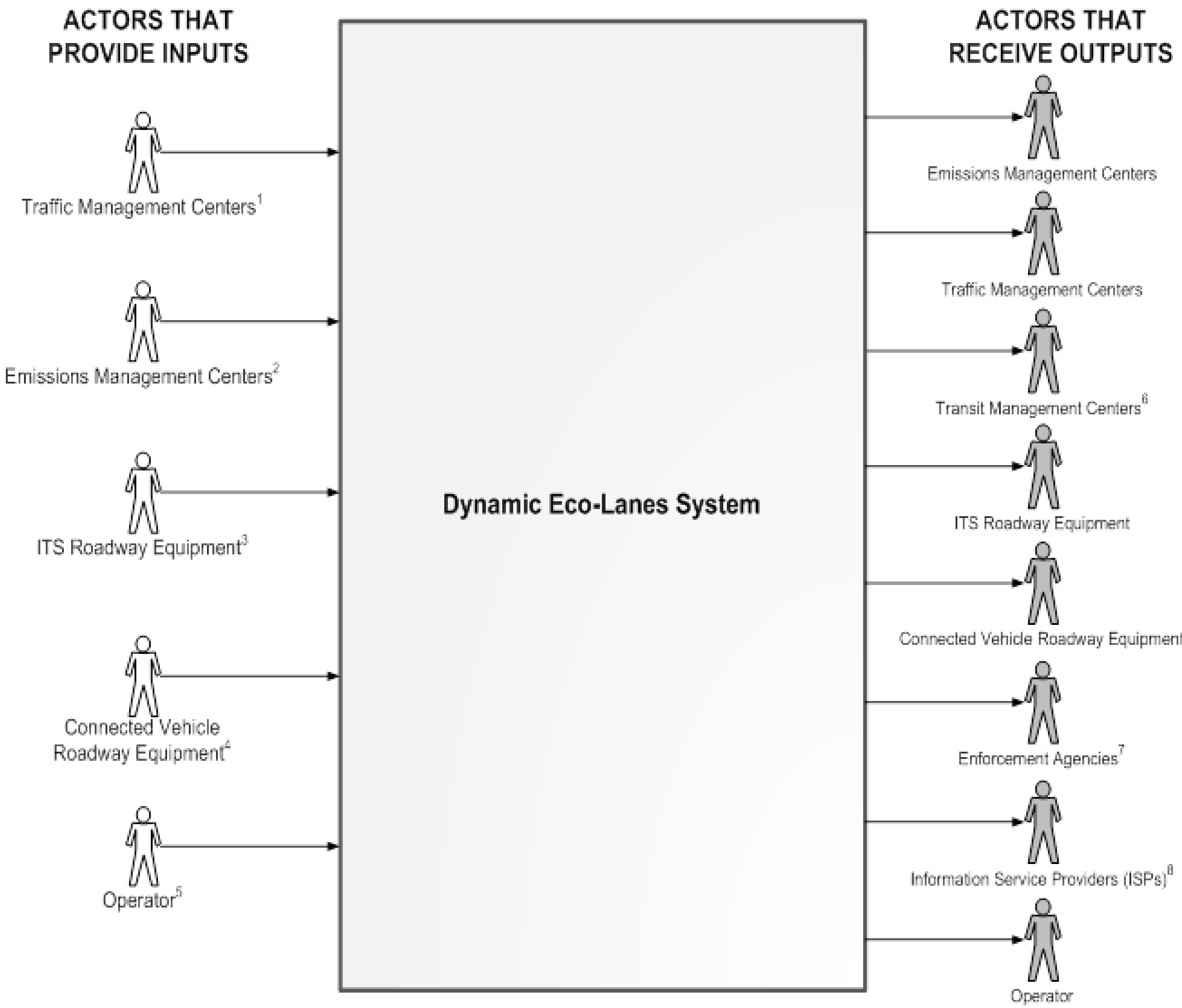
- System resides in a Traffic Management Center
- Integrated with existing ITS software (i.e., ATMS operating platforms)
- Deployed by state and local DOTs
- Collects V2I messages (e.g., probe messages and environmental messages) and data from conventional ITS devices
- Processes connected vehicle and 'conventional' data
- Implements operational strategy (e.g., eco-lane, eco-speed limits, etc.)
- Disseminates eco-lane parameters and traveler information

IN-VEHICLE SYSTEM

In-Vehicle System

- System resides in the vehicle
- Developed by automobile OEMs or aftermarket device vendors
- Collects vehicle diagnostics data, V2V messages, and V2I messages
- Provides V2V messages to other vehicles
- Provides V2I messages to Connected Vehicle Roadway Equipment
- Implements eco-driving strategies (e.g., CACC, etc.)

Dynamic Eco-Lanes 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 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.

3 ITS Roadway Equipment include roadway traffic sensors, environmental sensor stations, closed circuit television (CCTV) cameras, and other ITS equipment. Variable Speed limit Signs located in the field are also included.

4 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.

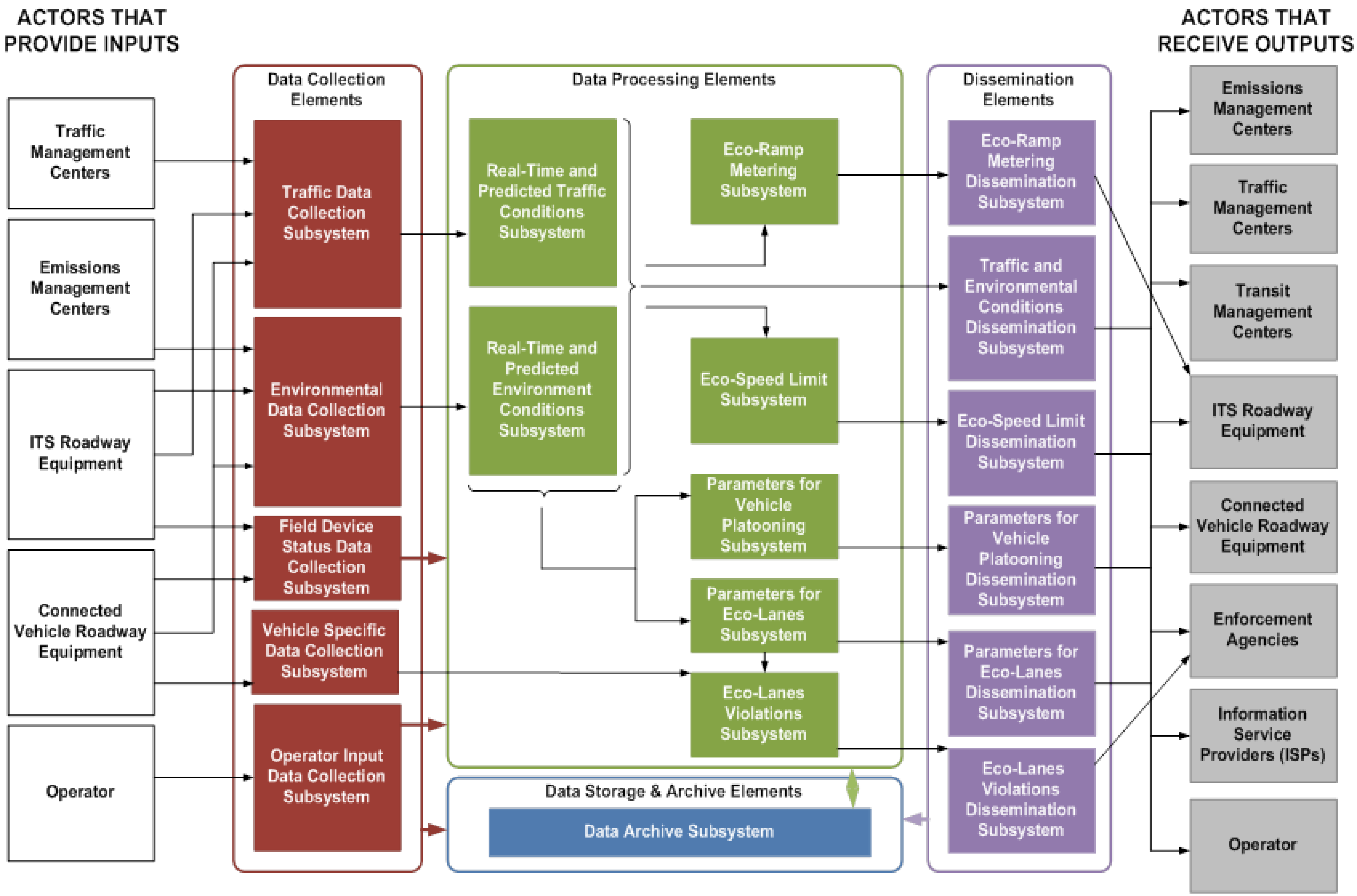
5 The Operator represents the human entity that directly interfaces with the system.

6 Transit Management Centers manage transit vehicle fleets and coordinates with other modes and transportation services.

7 Enforcement Agencies may perform enforcement functions of the rules and regulations of Eco-Lanes including entrance criteria and eco-speed limits.

8 Information Service Providers Information Service Providers are private entities that collect, process, store, and disseminate transportation information to system operators and the traveling public.

Dynamic Eco-Lanes System *(cont'd)*



Dynamic Eco-Lanes System | Data Collection Needs

ID	Title	Description
DELS-DC-01	Collect Traffic Data	**The Dynamic Eco-Lanes System needs to collect traffic data (e.g., volume, speed, occupancy, vehicle classification, incidents) for eco-lanes and regular lanes.** Traffic data may be obtained from traffic sensors that detect the presence of vehicles at locations along the network (e.g. using traffic sensors) or directly from messages collected from vehicles that measure a vehicle's speed, location, and other parameters.
DELS-DC-02	Collect Environmental Data	**The Dynamic Eco-Lanes System needs to collect environmental data (e.g. ambient air quality, vehicle emissions, temperature, and other road weather information).** Environmental data may be obtained from environmental sensors that collect weather and emissions data along the network (e.g. using environmental sensor stations) or directly from in-vehicle systems.
DELS-DC-03	Collect Field Device Status Data	**The Dynamic Eco-Lanes System needs to collect data on the operational status of Connected Vehicle and ITS Roadway Equipment.** These data include the operational status of RSE units and ITS field devices such as controllers at ramp meters and VSL signs.
DELS-DC-04	Collect Vehicle Specific Data	**The Dynamic Eco-Lanes System needs to collect vehicle-specific data about individual vehicles' parameters.** Vehicle specific data may include the vehicle's make and model, engine type, number of axles, average emissions, average fuel consumption, and unique identifier (e.g., license plate number or vehicle registration data).
DELS-DC-05	Collect Operator Input	**The Dynamic Eco-Lanes System needs to collect data entered by personnel operating the system.** This capability allows the operator to manually enter parameters for the dynamic eco-lanes.

Dynamic Eco-Lanes System | Data Processing Needs

ID	Title	Description
DELS-DP-01	Process Traffic Data	**The Dynamic Eco-Lanes 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., corridor and regional levels).** Traffic data should also be synthesized for differing time categories (e.g., times of day, day of week, holidays).
DELS-DP-02	Generate Predicted Traffic Conditions and Forecast Demand	**The Dynamic Eco-Lanes System needs to use historical and processed traffic data to predict traffic conditions aggregated at different levels (e.g., corridor, and regional levels).** The Dynamic Eco-Lanes System needs to collect traffic data from other systems, or produce and continually update, a predictive model of the traffic flow conditions on the road network.
DELS-DP-03	Process Environmental Data	**The Dynamic Eco-Lanes System needs to synthesize environmental data from multiple sources (e.g., fixed sensors, connected vehicle roadside equipment, other centers) to provide emissions analyses aggregated at different levels (e.g., corridor and regional levels).** The Dynamic Eco-Lanes System needs to process the environmental data being collected from sensors in the geographic area and from probe vehicles.
DELS-DP-04	Generate Predicted Emissions Profile	**The Dynamic Eco-Lanes System needs to synthesize environmental data from multiple sources (e.g., fixed sensors, connected vehicle roadside equipment, other centers) to generate predicted emissions aggregated at different levels (e.g., intersection, corridor, and regional levels).** This includes producing and continually updating a predictive model of the environmental conditions. The prediction may be based on historic data and current environmental conditions.

Dynamic Eco-Lanes System | Data Processing Needs

ID	Title	Description
DELS-DP-05	Generate Ramp Meter Timing Strategy	**The Dynamic Eco-Lanes System needs to generate ramp meter timing plans using processed traffic data, predicted traffic data, processed environmental data, and predicted emissions data.** Generating ramp meter timing plans may be similar to current adaptive ramp control systems; however the objective should be to generate timing plans to reduce overall emissions from bottlenecks forming on the freeway and emissions from vehicles on the ramp.
DELS-DP-06	Generate Eco-Speed Limits	**The Dynamic Eco-Lanes System needs to generate eco-speed limits using processed traffic data, predicted traffic data, weather information, and GHG and criteria pollutant information.** The purpose of eco-speed limits are to dynamically change speed limits approaching areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that impact flow or in response to predicted poor air quality conditions.
DELS-DP-07	Generate Vehicle Platooning Parameters	**The Dynamic Eco-Lanes System needs to generate parameters for vehicle platooning.** These parameters need to include geographic limits (start and end locations) for vehicle platooning capabilities as well as speed and gap strategies for the platoon.
DELS-DP-08	Create and Decommission Dynamic Eco-Lanes	**The Dynamic Eco-Lanes System needs to create and decommission Dynamic Eco-Lanes.** The system needs to use data collected from multiple sources (e.g., sensors, connected vehicle roadside equipment, and other centers) to determine whether conditions meet the criteria for the eco-lane.
DELS-DP-09	Detect Violations for Individual Vehicles	**The Dynamic Eco-Lanes System needs to determine violations for individual vehicles in the Eco-Lanes.** Violations include vehicles entering the eco-lanes that do not meet the parameters established for the eco-lanes.

Dynamic Eco-Lanes System | Dissemination Needs

ID	Title	Description
DELS-D-01	Provide Ramp Meter Timing Plans to Roadway Equipment	**The Dynamic Eco-Lanes System needs to provide ramp meter timing plans to the ramp meter controller.** These timing plans will be used by the ramp meter controller to implement ramp meter timing plans on freeway ramps.
DELS-D-02	Disseminate Traffic Conditions to Other Centers and ISPs	**The Dynamic Eco-Lanes System needs to disseminate traffic conditions to other centers to enable coordination of operational strategies for a corridor or a region.** Other centers may be adjacent geographically, under control of a different jurisdiction, or part of a more complex hierarchy. They may include public or private entities responsible for disseminating traveler information.
DELS-D-03	Disseminate Traffic Conditions for the Eco-Lanes and Regular Lanes to Vehicles	**The Dynamic Eco-Lanes System needs to provide traffic condition messages to vehicles for the eco-lanes and regular lanes.** These messages need to be formatted as output data for in-vehicle signage and should include information that would typically be displayed on a dynamic message sign (e.g., current traffic conditions, incidents, construction, and travel times).
DELS-D-04	Disseminate Environmental Conditions to Other Centers	**The Dynamic Eco-Lanes System needs to disseminate environmental data (e.g., regional and/or local air quality, temperature, precipitation) to other centers.** These data should be shared with other jurisdictions to enable coordination of advisory and operational strategies for a corridor or a region.
DELS-D-05	Disseminate Environmental Conditions to Vehicles	**The Dynamic Eco-Lanes System needs to provide environmental conditions messages to vehicles.** These messages would be presented to drivers to help them make informed travel decisions about their trips based on weather and environmental conditions (e.g., code red day alerts & weather conditions).

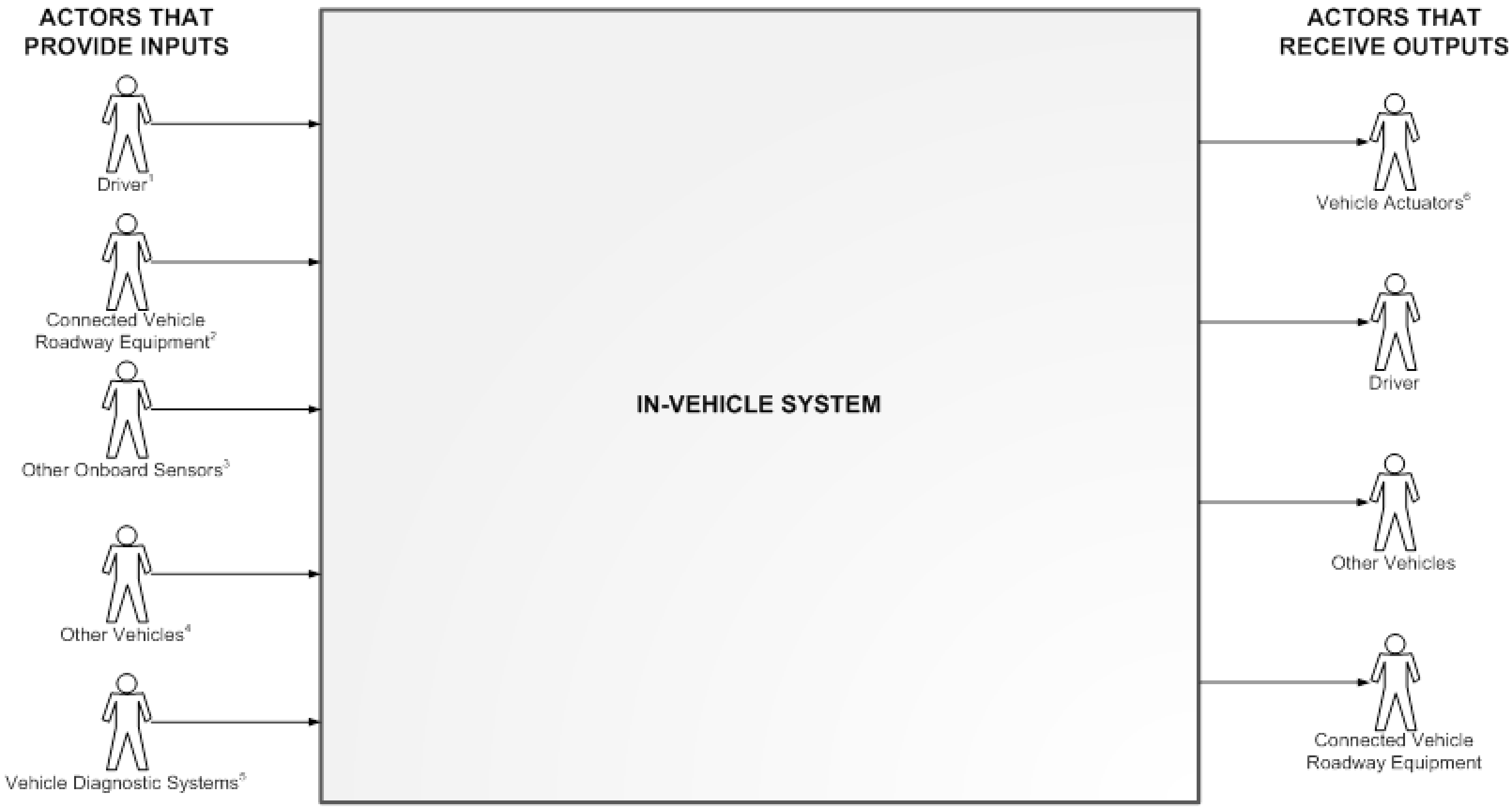
Dynamic Eco-Lanes System | Dissemination Needs

ID	Title	Description
DELS-D-06	Disseminate Eco-Speed Limits to Vehicles	**The Dynamic Eco-Lanes System needs to provide eco-speed limits to vehicles.** Dynamic Eco-Lanes System need to disseminate speed limits directly to vehicles traveling in eco-lanes as well as to VSL signs along an eco-lane. Eco-speed limits will provide drivers with an environmentally efficient speed to follow.
DELS-D-07	Disseminate Vehicle Platooning Parameters	**The Dynamic Eco-Lanes System needs to provide parameters about vehicle platooning to vehicles.** Vehicle platooning parameters include the geographic limits (start and end locations) for vehicle platooning capabilities as well as speed and gap strategies for the platoon.
DELS-D-08	Disseminate Eco-Lanes Parameters	**The Dynamic Eco-Lanes System needs to provide parameters about the eco-lanes to vehicles.** This information may include the location of the eco-lanes, start and end times for the eco-lanes, number of lanes on the freeway included in the eco-lanes, inductive charging capabilities in the eco-lanes, types of vehicles permitted in the eco-lanes (i.e., eco-lanes may be dedicated for transit vehicles, freight vehicles, or low emitting vehicles).
DELS-D-09	Provide Notice of Violation to Vehicles	**The Dynamic Eco-Lanes System needs to provide individual vehicles notice of a violation.** This notification may be sent as a message to in-vehicle systems or sent to roadway signage.
DELS-D-10	Notify Enforcement Agencies of Violations	**The Dynamic Eco-Lanes System needs to notify enforcement agencies of a violation.** This notification of a violation allows the Dynamic Eco-Lanes System to inform an enforcement agency that a vehicle violated the rules of the eco-lanes.

Dynamic Eco-Lanes System | Storage and Archive

ID	Title	Description
DELS-DA-01	Archive Data	**The Dynamic Eco-Lanes System needs to archive traffic data, environmental data, operations data (e.g., status of ramp meter or variable speed limit signs), and event logs (e.g., when the eco-lanes were commissioned or decommissioned, parameters of the eco-lanes, and , vehicle platooning parameters).** This capability allows the Dynamic Eco-Lanes System to keep a record of all data needed for reporting, developing predictive traffic models, developing the predicted emissions profiles, and assessing the impact of various applications on the environment.
DELS-DA-02	Determine Performance Measures	**The Dynamic Eco-Lanes System needs to determine performance measures and make them available to the operator.** Performance measures will be used to monitor the performance of the system.

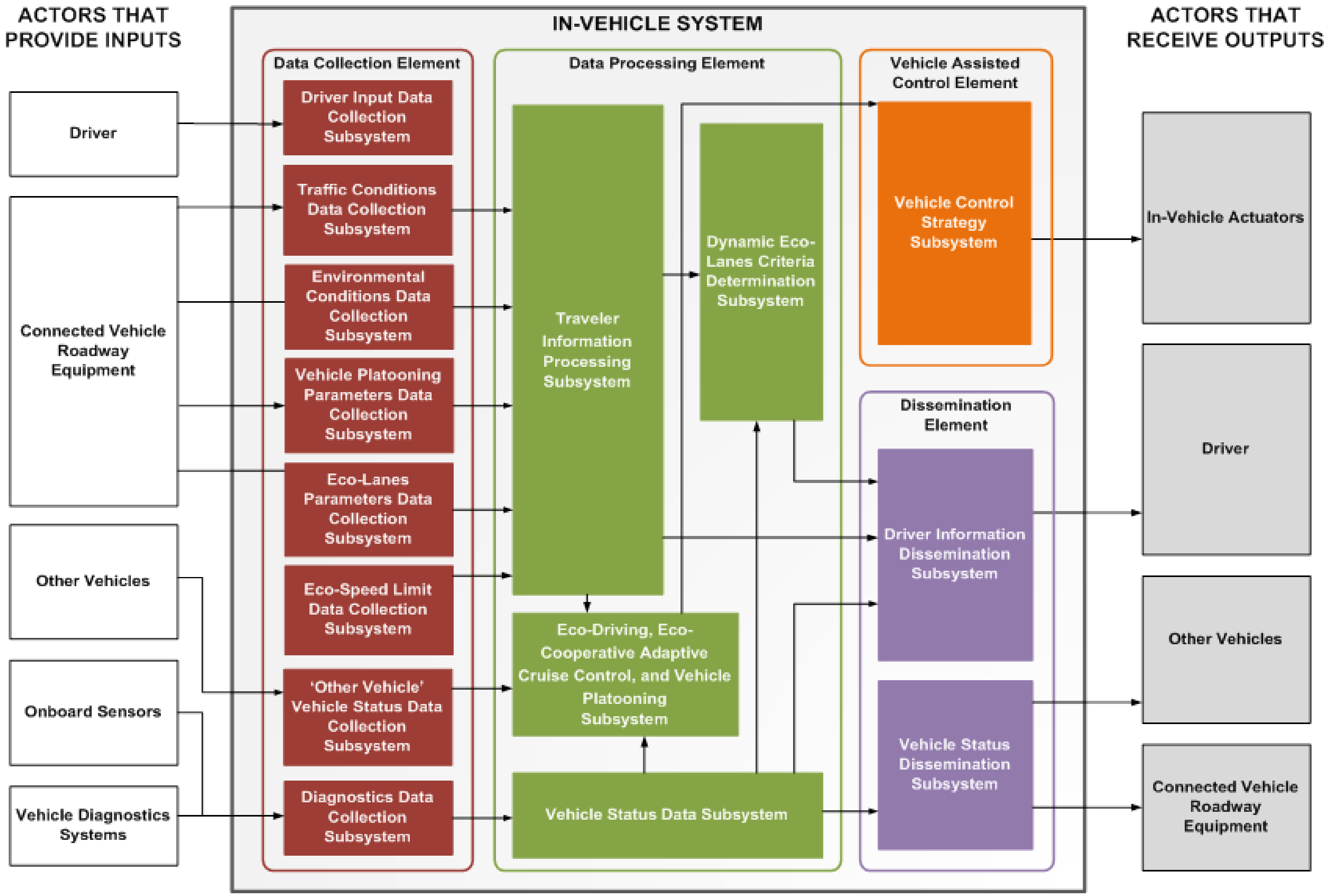
In-Vehicle System



Notes:

1. The Driver represents the human entity that operates a licensed vehicle on the roadway. The Driver inputs information such a 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. 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.
4. Other Vehicles include passenger, commercial, and transit vehicles that are enabled with Connected Vehicle technologies.
5. Vehicle Diagnostic Systems represent computer based systems, located on vehicles, designed to monitor the performance of some of the engine's major components.
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 vehicle characteristics.** The In-Vehicle system needs to support inputs from the driver allowing the driver to enable eco-driving, inductive charging, and CACC and vehicle platooning capabilities on the vehicle.
IVS-DC-02	Receive Traffic Conditions Data	**The In-Vehicle System needs to receive traffic conditions data.** This information would be provided to the driver of the vehicle allowing him or her to make pre-trip and en-route travel choices based on the traffic conditions including when to use the eco-lanes. Additionally, these data need to be used as inputs to eco-CACC and eco-driving strategies.
IVS-DC-03	Collect Geographic Information Description Data	**The In-Vehicle System needs to receive Geographic Information Description (GID) data. These data include descriptions about the static physical geometry at intersections and arterial roadway segments.** This information may include lane geometries and the allowable vehicle movements for each lane, barriers, pedestrian walkways, shared roadways, and rail lines that may affect vehicle movements. It also needs to include road grade information which would be used by the in-vehicle system to support eco-CACC applications.

In-Vehicle System | Data Collection Needs

ID	Title	Description
IVS-DC-04	Receive Environmental Conditions Data	**The In-Vehicle System needs to receive environmental conditions data. These data may include real-time and predicted environmental and air quality conditions that would typically be displayed on a dynamic message sign (e.g., code red day alerts).** The In-Vehicle System needs to provide this information to drivers allowing them to make pre-trip and en-route travel choices based on the environmental conditions. Road weather information may also be used as input to eco-CACC and eco-driving applications.
IVS-DC-05	Receive Vehicle Platooning Parameters	**The In-Vehicle System needs to receive vehicle platooning parameters from the Dynamic Eco-Lanes System and from vehicle platoons.** Vehicle platooning parameters allow an individual vehicle to enter a platoon based on data received from the entity operating the roadway, other vehicles, and vehicle platoons. These parameters may include the geographic limits (start and end locations) for vehicle platooning capabilities, and speed and gap strategies for the platoon.
IVS-DC-06	Receive Eco-Lanes Parameter Information	**The In-Vehicle System needs to receive parameters about Dynamic Eco-Lanes that have been created and decommissioned.** This information should include parameters to ensure that drivers receive necessary information about the eco-lanes, including the location of the eco-lanes, start and end times for the eco-lanes, number of lanes, location of inductive charging infrastructure, as well as the criteria for vehicles entering the eco-lane.

In-Vehicle System | Data Collection Needs

ID	Title	Description
IVS-DC-07	Receive Eco-Speed Limits	**The In-Vehicle System needs to receive lane specific eco-speed limits broadcasted from Connected Vehicle Roadway Equipment.** Eco-speed limits will provide drivers with an environmentally efficient speed to follow. These speed limits may be dynamic based on real-time and predicted traffic and environmental conditions. Eco-speed limits need to be received by the in-vehicle system and presented to the driver.
IVS-DC-08	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, braking status, and size).** These data will be used by the In-Vehicle System for eco-CACC and vehicle platooning to couple vehicles together and avoid a collision between two vehicles.
IVS-DC-09	Collect Vehicle Diagnostics Data	**The In-Vehicle System needs to collect diagnostics data from onboard systems and onboard sensors located on the vehicle to obtain vehicle status and vehicle emissions data.** Vehicle diagnostic data includes data from the controller area network (CAN) bus, GPS, environmental sensors, and other sensors located on the vehicle. This includes data about the vehicle's location, speed, acceleration, trajectory, vehicle type, engine type, fuel consumption, and emissions.
IVS-DC-10	Receive Inductive Charge	**Electric Vehicles need to receive inductive charges from wireless inductive charging pads.** Electric vehicles need to receive energy sent through inductive coupling to an electrical device, which can use that energy to charge a vehicle's battery. This need supports inductive charging of electric vehicles.

In-Vehicle System | Data Processing Needs

ID	Title	Description
IVS-DP-01	Generate Eco-Driving Strategies	**The In-Vehicle System needs to determine driving recommendations with the objective of promoting a driving style that lowers vehicle emissions.** These driving recommendations may include advice about recommended speeds, accelerations, and decelerations based on upcoming traffic conditions, and roadway geometry and potential interactions with nearby vehicles.
IVS-DP-02	Determine if Vehicle Meets Criteria for Vehicle Platooning	**The In-Vehicle System needs to determine if the vehicle meets the criteria for entering a vehicle platoon.** Upon receiving parameters for vehicle platooning, the In-Vehicle System needs to determine if the vehicle meets the requirements to join a vehicle platoon. Criteria that the In-Vehicle System may consider include the vehicle type, vehicle credentials are met allowing the vehicle to join a platoon, vehicle sensors are working properly, or other parameters established by the entity responsible for operating the eco-lane.
IVS-DP-03	Generate Eco-Cooperative Adaptive Cruise Control and Vehicle Platooning Strategies	**The In-Vehicle System needs to generate eco-CACC and vehicle platooning strategies that may include vehicle control of accelerations and declarations based on traffic and environmental conditions, eco-speed limits, and interactions with surrounding vehicles.** The system needs to quickly and reliably generate speed and gap decisions by interpreting internal vehicle data with data received from other vehicles. This would enable the vehicle to follow a lead vehicle very closely (inches apart) in a platoon, responding to changes in speed and direction of the lead vehicle.

In-Vehicle System | Data Processing Needs

ID	Title	Description
IVS-DP-04	Determine if the Vehicle Meets Criteria to Enter the Dynamic Eco-Lanes	**The In-Vehicle System needs to determine if the vehicle meets the criteria for entering the Dynamic Eco-Lanes.** Upon receiving parameters for the Dynamic Eco-Lanes, the In-Vehicle System needs to use vehicle diagnostics data and other data collected from vehicle systems to determine if the vehicle is permitted to use the eco-lanes. Criteria that the In-Vehicle System may consider include the vehicle type, average fuel consumption, average vehicle emissions, capability of receiving onboard VSL messages, or other parameters established by the entity responsible for operating the eco-lane.
IVS-DP-05	Process Traffic and Environmental Data for Traveler Information Messages	**The In-Vehicle System needs to process traffic and environmental data and develop traveler information messages to be provided to the driver.** Traffic data may include information of traffic conditions including travel times, incidents, and construction activities. Environmental data may include information about weather conditions or air quality conditions that may be of value to the driver. These data need to be synthesized and packaged for traveler information messages that would be provided to the driver.
IVS-DP-06	Determine Vehicle Emissions Data	**The In-Vehicle System needs to calculate estimates of tailpipe emissions and fuel consumption if this data cannot be collected directly from the vehicle.** These estimates may be based on data collected from sensors located on the vehicle. Information such as the vehicle type, engine type, fuel type, second-by-second speed and acceleration, and accessory use may be used to estimate tailpipe emissions and fuel consumption. If these values are transmitted to the infrastructure, the emissions and fuel use need not be computed by the vehicle; instead emissions may be estimated at a center.

In-Vehicle System | Dissemination Needs

ID	Title	Description
IVS-D-01	Disseminate Vehicle Status Data	**The In-Vehicle System needs to transmit 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).** This information needs to be sent to the connected vehicle infrastructure prior to and when a vehicle is in the eco-lane. Additionally, vehicles need to provide vehicle status data to other vehicles to enable eco-CACC and vehicle platooning capabilities.
IVS-D-02	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.** The environmental data message includes data such as the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption. These data are needed to determine if an individual is permitted to enter the eco-lanes. Additionally, this information may be disseminated to the Dynamic Eco-Lanes System as input for determining when an eco-lane should be established or decommissioned.
IVS-D-03	Provide Traffic Conditions to the Driver	**The In-Vehicle System needs to provide traffic conditions to drivers so they can make informed decisions during their trips.** This information may include travel times for the eco-lanes and regular lanes. This information would be provided to drivers of the vehicles allowing them to make pre-trip and en-route travel choices based on the traffic conditions. These data may assist travelers in determining trips into the eco-lanes.

In-Vehicle System | Dissemination Needs

ID	Title	Description
IVS-D-04	Provide Environmental Conditions to the Driver	**The In-Vehicle System needs to provide environmental conditions to the driver so they can make informed decisions during their trip.** These data may include real-time and predicted environmental and air quality conditions that would typically be displayed on a dynamic message sign (e.g., code red day alerts). This information may also include estimated fuel consumption along a roadway segment comparing the eco-lanes to the regular lanes.
IVS-D-05	Provide Eco-Lanes Parameters to the Driver	**The In-Vehicle System needs to provide eco-lane parameters to the driver and inform the driver if his/her vehicle meets the criteria for entering the eco-lanes.** These parameters may include entrance parameters for the eco-lanes (e.g. vehicle type or fuel type), location (start and end), start and end time, or other rules that may be created by the eco-lanes operating entity. If there are restrictions to using the eco-lanes, the In-Vehicle System needs to inform the driver if his/her vehicle is permitted to use the lanes.
IVS-D-06	Provide Vehicle Platooning Parameters to the Driver	**The In-Vehicle System needs to provide vehicle platooning parameters to the driver and inform the driver if his/her vehicle meets the criteria for entering a vehicle platoon.** The In-Vehicle System needs to inform the driver of vehicle platooning parameters prior to entering the platoon. This may include the geographic limits (start and end locations) for vehicle platooning capabilities and speed and gap strategies for the platoon.
IVS-D-07	Provide Eco-Driving Information to the Driver	**The In-Vehicle System needs to provide eco-driving information to drivers that encourage them to drive in a more environmentally efficient manner.** This information may include recommended speeds, accelerations, and changing of gears.

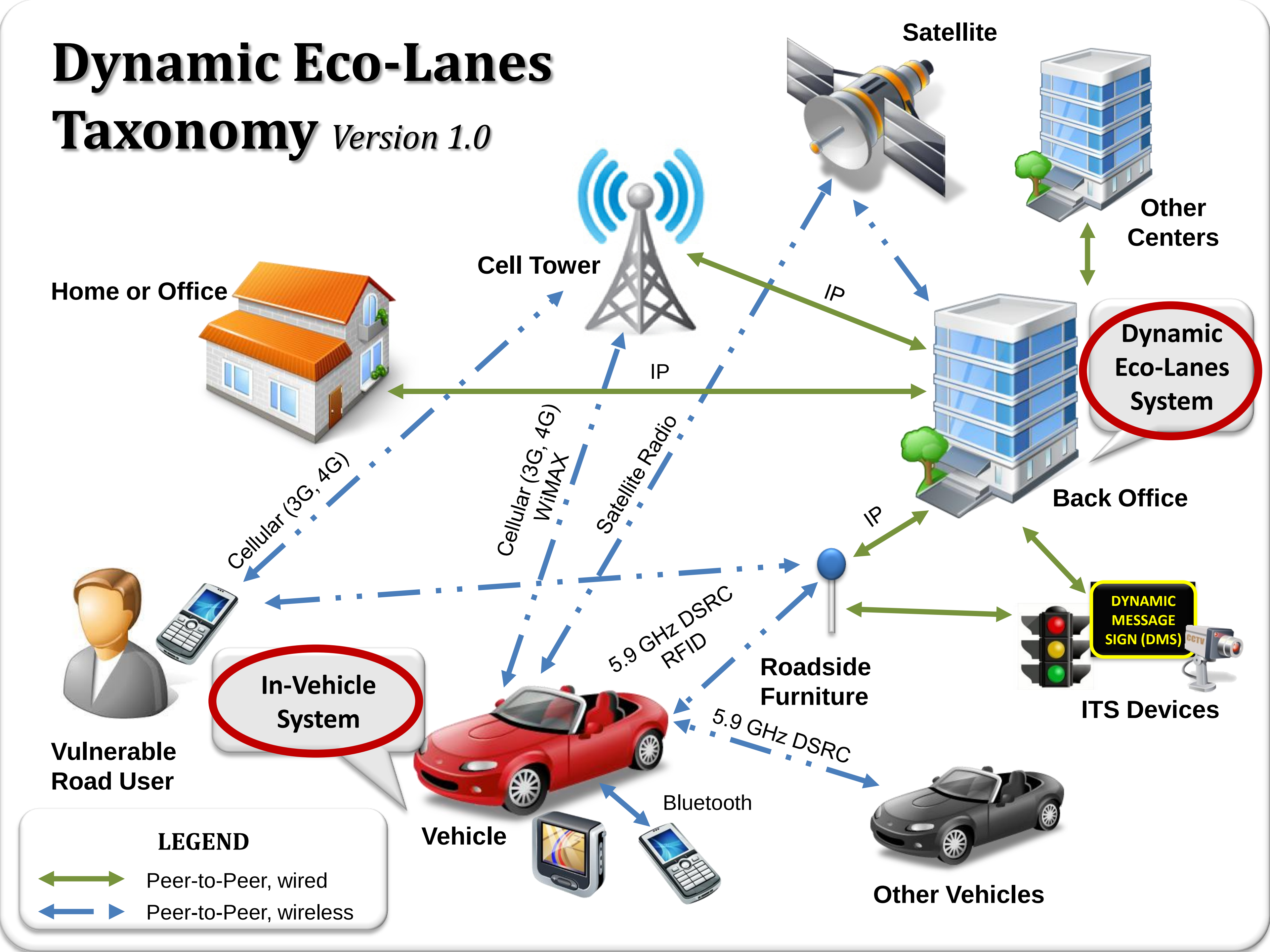
In-Vehicle System | Vehicle Control

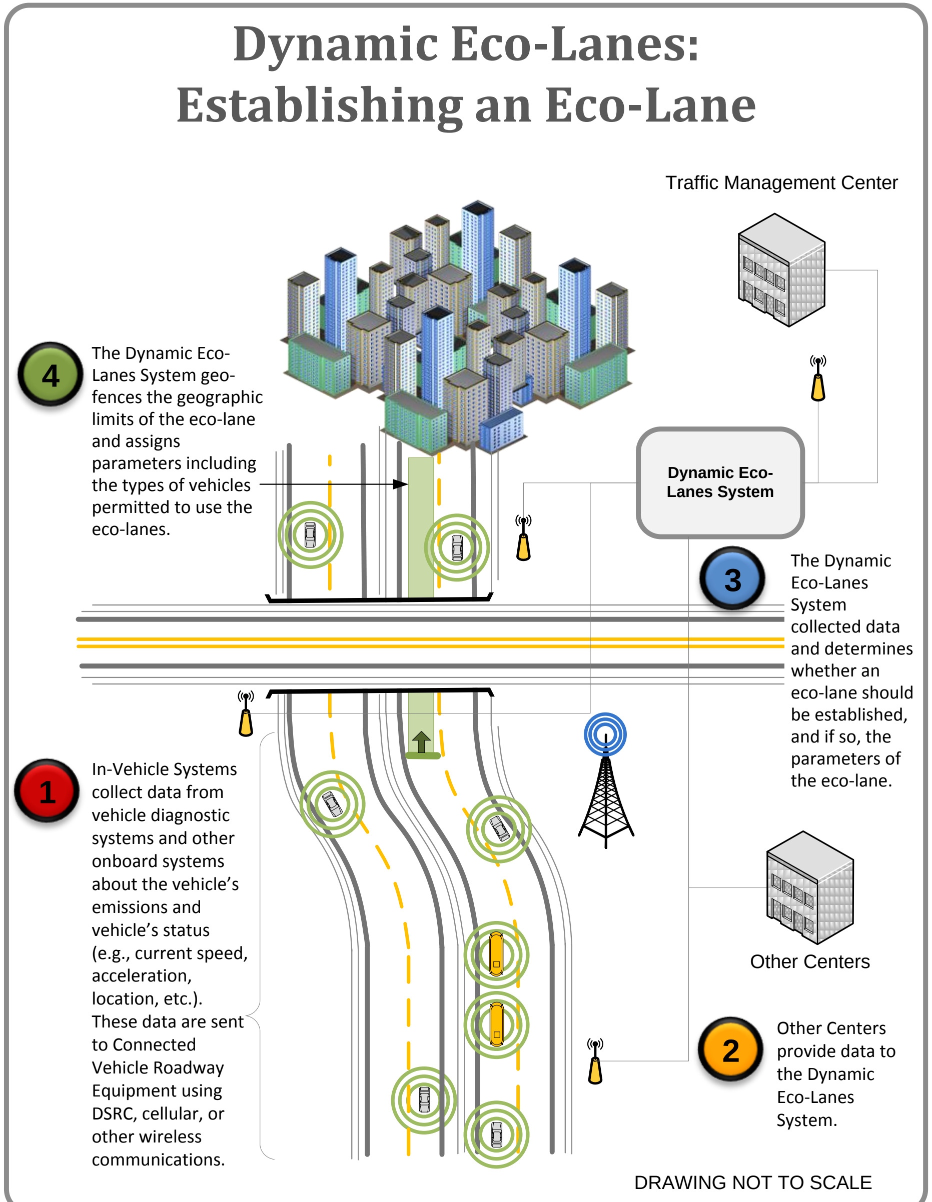
ID	Title	Description
IVS-VC-01	Provide Eco-Driving Vehicle Assisted Control Strategy	**The In-Vehicle System needs to process and provide data to vehicle actuators to support vehicle assisted and autonomous driving vehicle controls.** This allows for vehicle assisted or automated control of the vehicle based on outputs from applications (e.g., eco- cooperative adaptive cruise control or vehicle platooning), vehicle sensors, and vehicle status messages received from other vehicles.

In-Vehicle System | Operator Interface

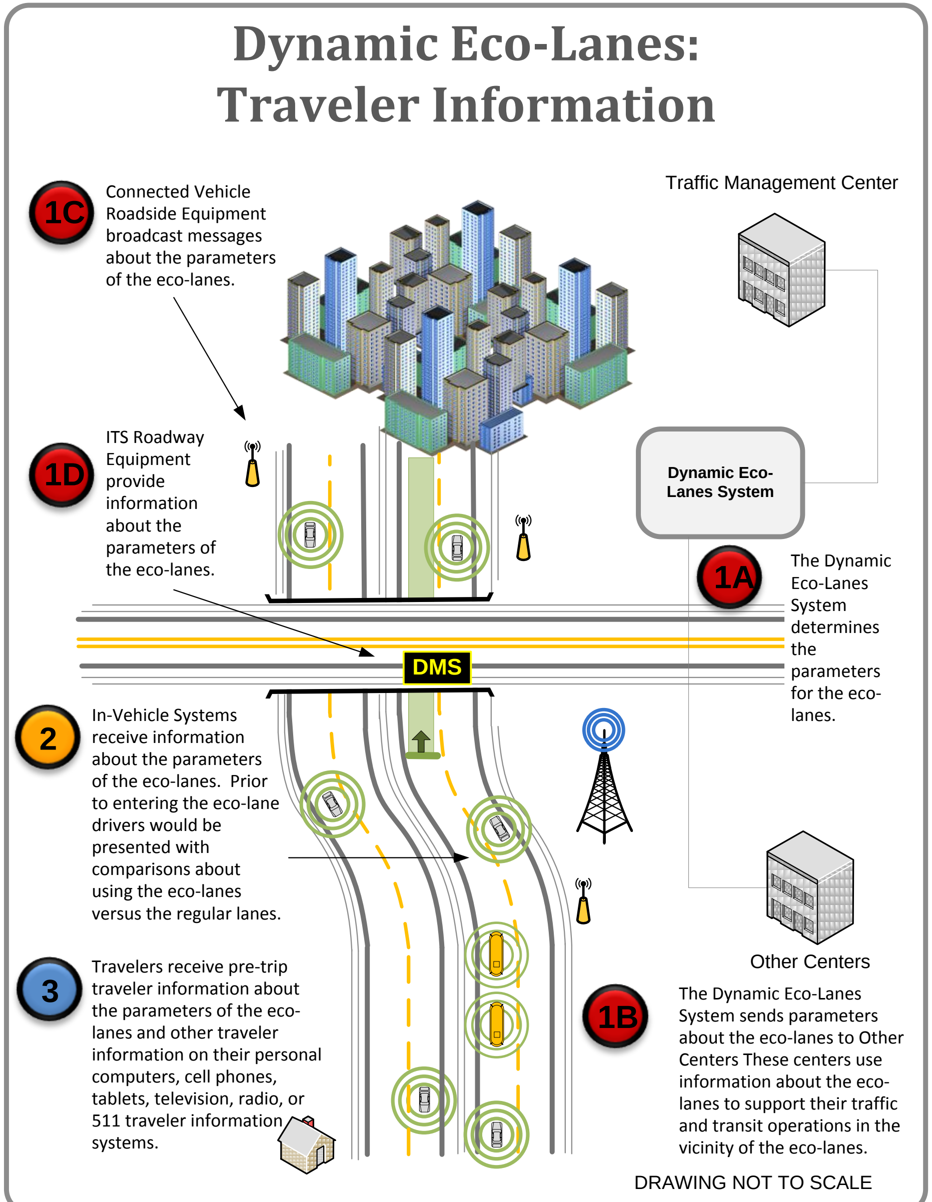
ID	Title	Description
IVS-OI-01	Provide Operator Interface	**The In-Vehicle System needs to provide a user interface through which traffic conditions, environmental conditions, driving recommendations, eco-lanes parameters, and vehicle platooning parameters, battery charge and feedback on driving behavior can be displayed to the driver. The interface also needs to allow the user to opt-in to applications.** The interface needs to allow the driver to enter information for route guidance capabilities. User-configurable traffic and environmental condition alert subscriptions need to be supported and resultant alerts may be output to the driver. In-vehicle signage needs to be output to the driver; including eco-speed limits, traffic conditions, and environmental conditions such as that typically displayed on a dynamic message sign (DMS). The interface also needs to provide drivers with speed recommendations that support eco-driving. Finally, drivers need to be able to receive information from vehicle systems about an electric vehicle's charge and the charge received through inductive charging.

3. SCENARIOS

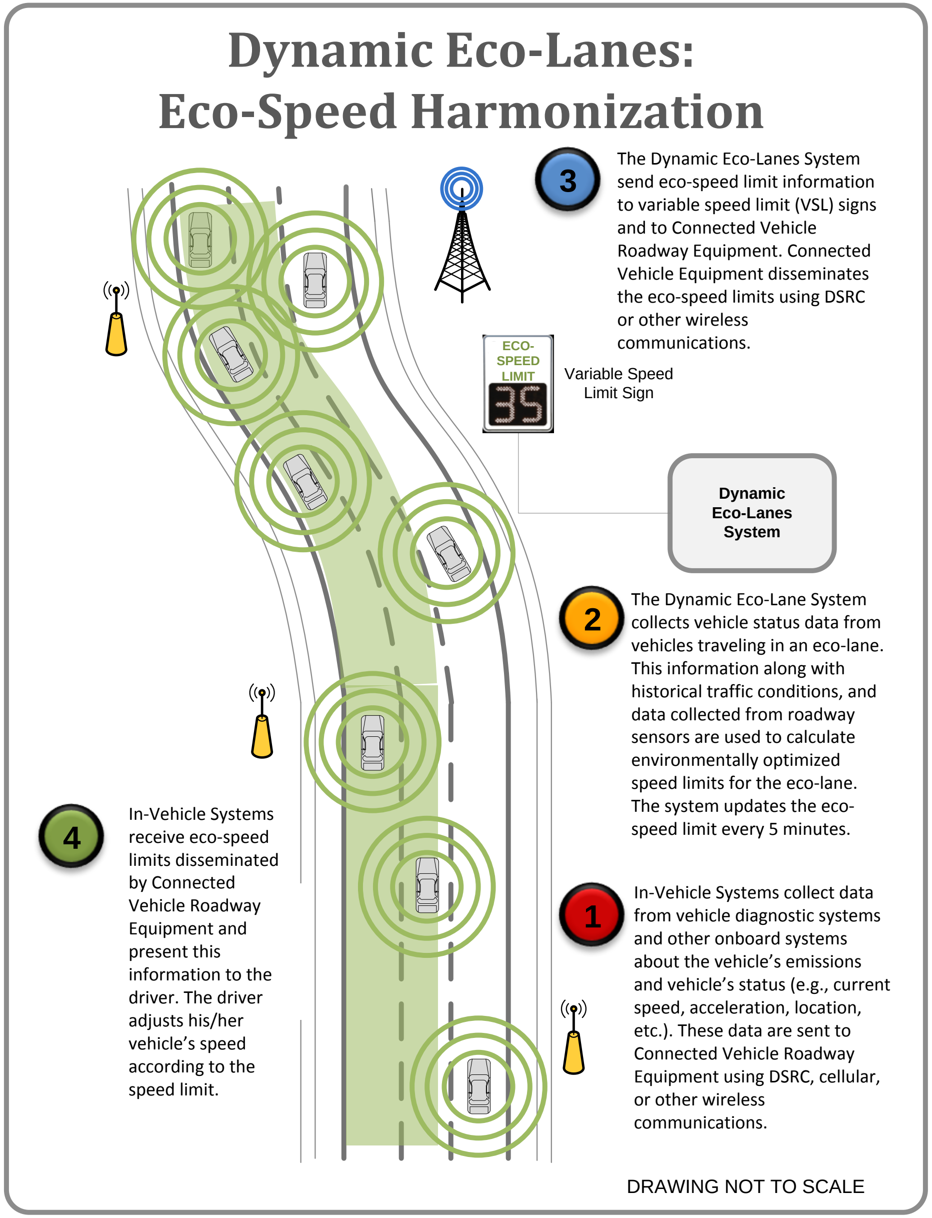

Dynamic Eco-Lanes
Taxonomy Version 1.0
Satellite
Other Centers
Cell Tower
Home or Office
IP
IP
Dynamic Eco-Lanes System
Back Office
Cellular (3G, 4G)
Cellular (3G, 4G) WiMAX
Satellite Radio
IP
DYNAMIC MESSAGE SIGN (DMS)
CCTV
5.9 GHz DSRC
RFID
Roadside Furniture
ITS Devices
In-Vehicle System
Vulnerable Road User
5.9 GHz DSRC
Bluetooth
Vehicle
Other Vehicles
LEGEND
Peer-to-Peer, wired
Peer-to-Peer, wireless



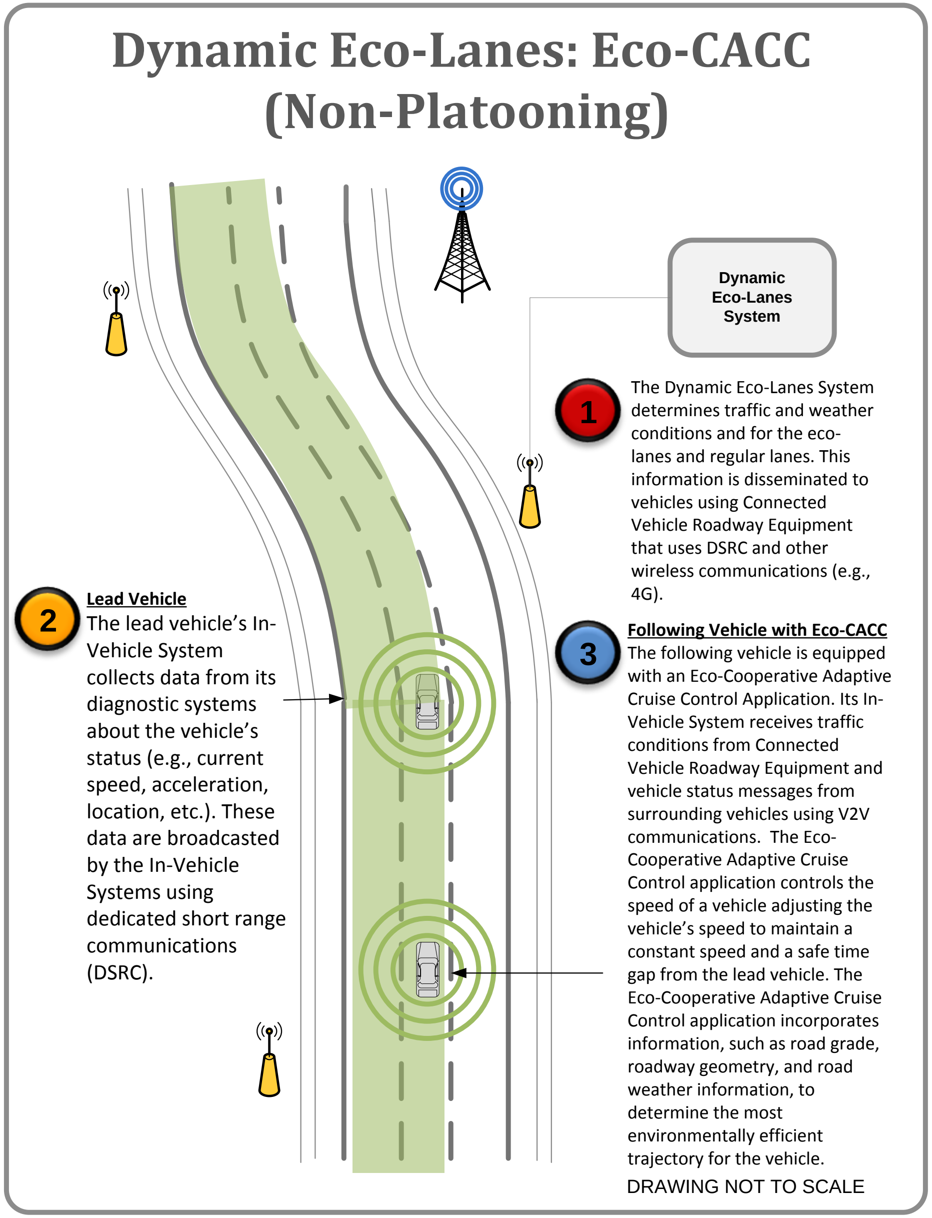
Step	Description
1	**In-Vehicle Systems collect data from vehicle diagnostic systems and other onboard systems about the vehicle's emissions and vehicle's status (e.g., current speed, acceleration, location, etc.). These data are sent to Connected Vehicle Roadway Equipment using DSRC, cellular, or other wireless communications**.
2	**Other Centers provide traffic, environmental, and transit data to the Dynamic Eco-Lanes System. Traffic data includes volumes, speeds, occupancy, travel times, incidents, or other traffic data collected by a Traffic Management Center.** These data may be collected using ITS Roadway Equipment such as traffic sensors, probe vehicles, or other ITS technologies. **Environmental data includes air quality data or weather data collected by Emissions Management Centers.**
3	**The Dynamic Eco-Lanes System uses the data collected from Connected Vehicle Roadway Equipment, ITS Roadway Equipment, and Other Centers** to determine whether an eco-lane should be established, and if so, the parameters of the eco-lane. **These parameters include the geographic limits of the eco-lane, the duration of the eco-lane, and types of vehicle permitted to use the eco-lanes (i.e., the eco-lanes may restrict high emitting vehicles from using the lanes).**
4	The eco-lane is established by the Dynamic Eco-Lanes System and is approved by the operator. **The Dynamic Eco-Lanes System geo-fences the geographic limits of the eco-lane and assigns parameters including the types of vehicles permitted to use the eco-lanes.**



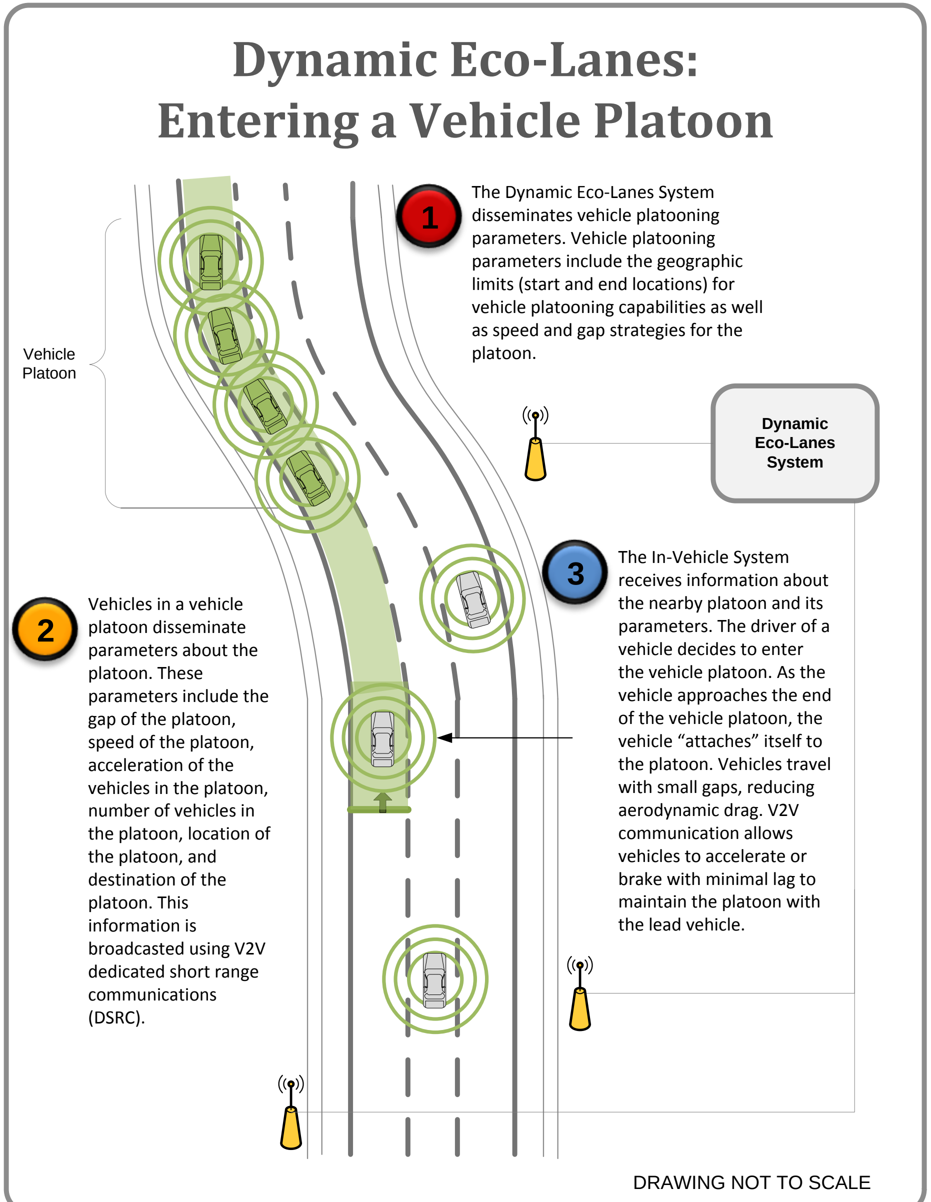
Step	Description
1	**Step 1 A |** The Dynamic Eco-Lanes System determines the parameters for the eco-lanes. **Step 1 B | The Dynamic Eco-Lanes System sends parameters about the eco-lanes to Other Centers such as Traffic Management Centers and Transit Management Centers.** These centers use information about the eco-lanes to support their traffic and transit operations in the vicinity of the eco-lanes. **Step 1 C | Connected Vehicle Roadside Equipment broadcast messages about the parameters of the eco-lanes.** Messages may be broadcast using DSRC communications or other wireless communications (e.g., 4G). **Step 1 D | ITS Roadway Equipment including Dynamic Message Signs and 511 Systems provide information about the parameters of the eco-lanes.**
2	**In-Vehicle Systems receive information about the parameters of the eco-lanes.** This information is presented to drivers to assist them in making informed en-route travel choices as they approach the eco-lane. **Prior to entering the eco-lane, drivers would be presented with comparisons of travel times and estimated fuel consumption for using the eco-lanes versus the regular lanes.** The traveler information would also inform the driver if his or her vehicle is permitted to use the eco-lane.
3	**Travelers receive pre-trip traveler information about the parameters of the eco-lanes and other traveler information. This information may be received by travelers from Information Service Providers on their personal computers, cell phones, tablets, television, radio, or 511 traveler information systems. Travelers use this information to plan their trips accordingly.** For example, upon receiving information about the eco-lanes, travelers may to use their alternative fuel vehicle to drive into Metropolis City.



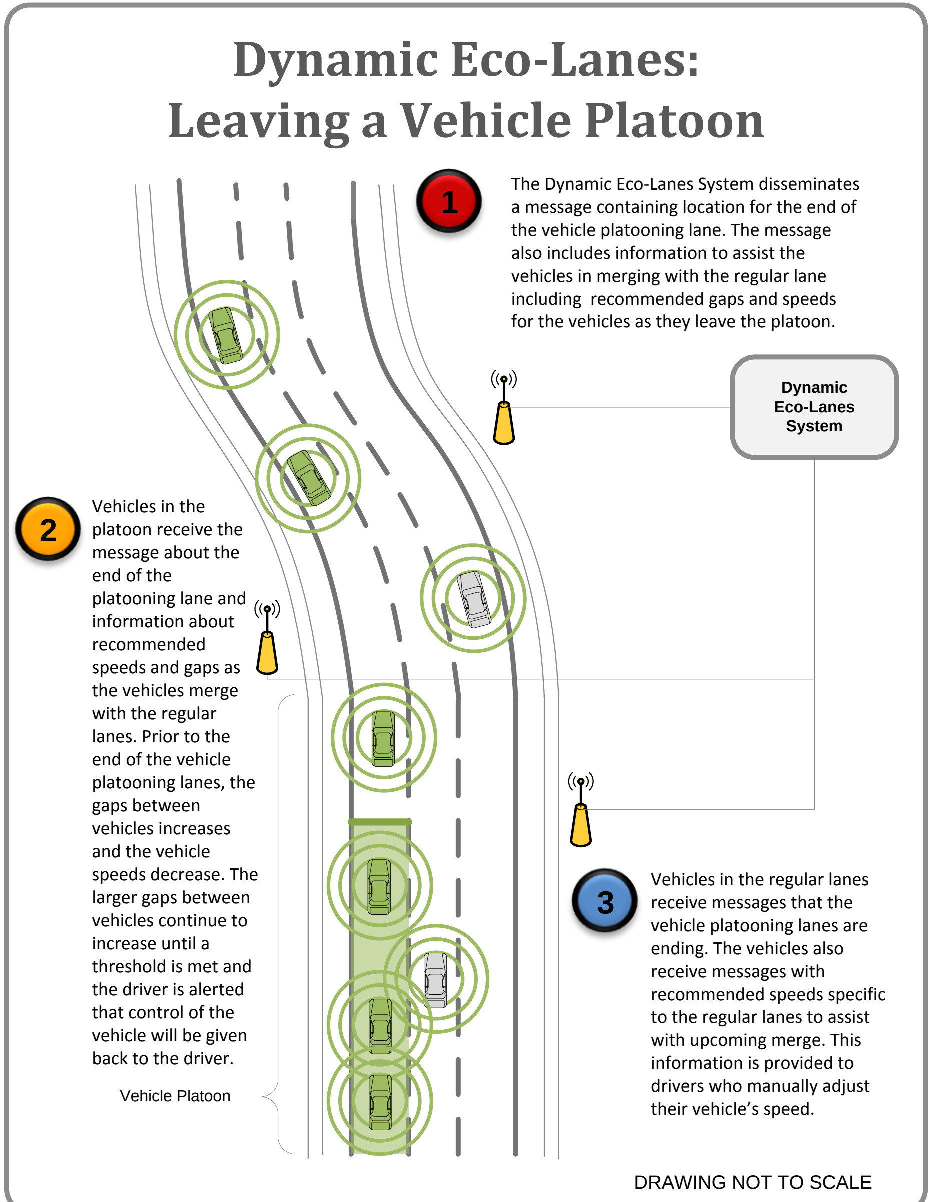
Step	Description
1	**In-Vehicle Systems collect data from vehicle diagnostic systems and other onboard systems about the vehicle's emissions and vehicle's status (e.g., current speed, acceleration, location, etc.). These data are sent to Connected Vehicle Roadway Equipment using DSRC, cellular, or other wireless communications.**
2	**The Dynamic Eco-Lanes System collects vehicle status data from vehicles traveling in an eco-lane. This information along with historical traffic conditions, and data collected from roadway sensors are used to calculate environmentally optimized speed limits for the eco-lane(s).** The speed limits also consider congestion and incidents to slow the speed of vehicles approaching the back of a queue. **Eco-speed limits are determined for each roadway segment and are specific to a travel lane. Lane specific eco-speed limits need to be determined to differentiate speeds for eco-lanes versus regular lanes running adjacent to the eco-lanes.** The system **updates the eco-speed limit every 5 minutes** based on real-time and predicted traffic conditions.
3	**The Dynamic Eco-Lanes System sends eco-speed limit information to VSL signs and to Connected Vehicle Roadway Equipment.**
4	**In-Vehicle Systems receive eco-speed limits disseminated by Connected Vehicle Roadway Equipment and present this information to the driver.** The eco-speed limits are lane specific, so the speed limits allow the eco-lanes to be different than the speed limits for the regular lanes. **Upon receiving the eco-speed limits, drivers adjust their vehicle's speed accordingly. In the future, if automated systems are incorporated into vehicles, the vehicle may automatically adjust its speed according to the eco-speed limit.**



Step	Description
1	**The Dynamic Eco-Lanes System determines traffic and weather conditions and for the eco-lanes and regular lanes. This information includes average speeds for roadway segments, incidents, lane closures, construction and maintenance activities, and road weather conditions.** Traffic and weather messages are disseminated to vehicles using Connected Vehicle Roadway Equipment that uses DSRC and other wireless communications (e.g., 4G).
2	**The lead vehicle's In-Vehicle System collects data from its diagnostic systems about the vehicle's status (e.g., current speed, acceleration, location, etc.). These data are broadcasted by the In-Vehicle Systems using DSRC.**
3	**The following vehicle is equipped with an Eco-Cooperative Adaptive Cruise Control Application. Its In-Vehicle System receives traffic conditions from Connected Vehicle Roadway Equipment and vehicle status messages from surrounding vehicles using V2V communications. V2V messages from the lead vehicle are received at a rate of ten times per second. The Driver activates the Eco-Cooperative Adaptive Cruise Control application setting a desired or acceptable gap between his/her vehicle and the lead vehicle.** The Eco-Cooperative Adaptive Cruise Control application controls the speed of a vehicle adjusting the vehicle's speed to maintain a constant speed and a safe time gap from the lead vehicle. **The Eco-Cooperative Adaptive Cruise Control application incorporates information, such as down stream traffic conditions, road grade, roadway geometry, and road weather information, to determine the most environmentally efficient trajectory for the vehicle.** *Note: Road grade and road geometry data are collected from the In-Vehicle System's map.*

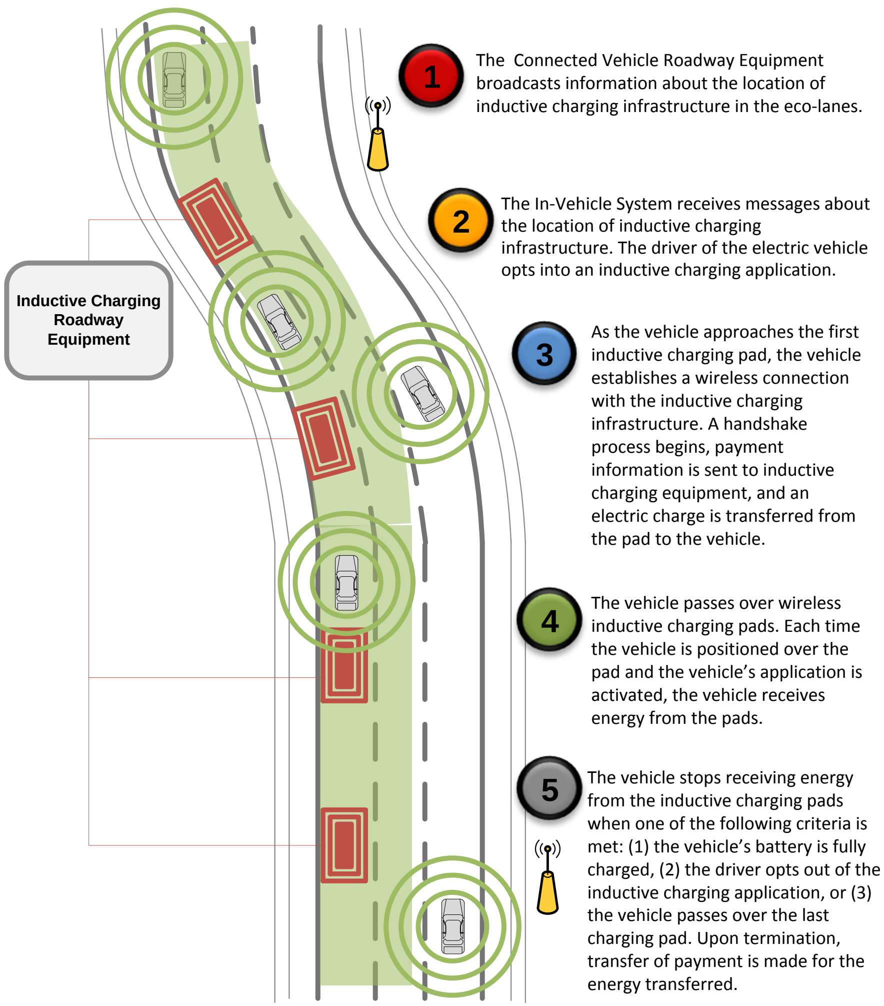


Step	Description
1	**The Dynamic Eco-Lanes System disseminates vehicle platooning parameters including the geographic limits (start and end locations) for vehicle platooning capabilities, as well as, speed, and gap strategies for the platoon.**
2	**Vehicles in a vehicle platoon disseminate parameters about the platoon including the speed of the platoon, number of vehicles in the platoon, location of the platoon, and type of vehicles in the platoon (e.g., platoons may be limited to trucks or transit vehicles).** This information is broadcast using V2V DSRC. *Note: The lead vehicle in the platoon is an autonomous vehicle.*
3	**A vehicle approaching the back of the platoon meets the security requirements to enter the platoon and has been approved by the operating entity to join the platoon. The vehicle’s In-Vehicle System receives information about the nearby platoon and its parameters.** As the vehicle approaches the end of the vehicle platoon, **the driver confirms through the In-Vehicle System that he wants to join the platoon. The vehicle’s In-Vehicle System sends a message to the last vehicle in the platoon requesting the vehicle to join the platoon. The last vehicle in the platoon accepts the request. The vehicle “attaches” itself to the platoon**. The driver is notified that he has joined the platoon and has been **released from lateral and longitudinal movement of the vehicle while his vehicle is in the platoon.** Vehicles travel with small gaps, reducing aerodynamic drag. V2V communication allows vehicles to accelerate or brake with minimal lag to maintain the platoon with the lead vehicle. The reduction in drag results in reduced fuel consumption, greater fuel efficiency, and less pollution for vehicles.



Step	Description
1	**The Dynamic Eco-Lanes System disseminates a message containing location for the end of the vehicle platooning lane. The message also includes information to assist the vehicles in the vehicle platoon in merging with the regular lanes including recommended gaps and speeds for the vehicles as they leave the platoon.** These recommended speeds and gaps are based on real-time traffic conditions in the eco-lanes and regular lanes. **The message is broadcasted by Connected Vehicle Roadway Equipment using DSRC or other wireless communications (e.g., 4G).**
2	**Vehicles in the platoon receive the message about the end of the platooning lane and information about recommended speeds and gaps** as the vehicles merge with the regular lanes. **Prior to the end of the vehicle platooning lanes, the gaps between vehicles increases and the vehicle speeds decrease. The larger gaps between vehicles continue to increase until a threshold is met and the driver is alerted that control of the vehicle will be given back to the driver.**
3	**Vehicles in the regular lanes receive messages that the vehicle platooning lanes are ending. The vehicles also receive messages with recommended speeds specific to the regular lanes to assist with upcoming merge and possibly messages directing them to move to the right lane.** This information is provided to drivers who manually adjust their vehicle's speed.

Dynamic Eco-Lanes: Dynamic Inductive Charging



DRAWING NOT TO SCALE

Step	Description
1	The Connected Vehicle Roadway Equipment broadcasts parameters about the eco-lanes. **These parameters include information about the location of inductive charging infrastructure in the eco-lanes.**
2	**The In-Vehicle System receives messages about the parameters for the eco-lanes – 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.
3	**As the vehicle approaches the first inductive charging pad, the vehicle establishes a wireless connection with the inductive charging infrastructure. A handshake process begins, payment information is sent to inductive charging equipment, and an electric charge is transferred from the pad to the vehicle.**
4	**As the vehicle drives in the eco-lanes, it passes over wireless inductive charging pads.** Each time the vehicle is positioned over the pad and the vehicle's application is activated, the vehicle receives energy from the pads. **A series of inductive charging pads embedded in the roadway enable 'dynamic charging' which allows charging of vehicles in motion.**
5	**The vehicle stops receiving energy from the inductive charging pads when one of the following criteria is met: (1) the vehicle's battery is fully charged, (2) the driver opts out of the inductive charging application, or (3) the vehicle passes over the last charging pad. Upon termination, transfer of payment is made for the energy transferred.**

4. 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)*

• **Reduce Emissions from Surface Transportation Vehicles**
  • Reduce CO_2, CO, NO_X, SO_2, PM_{10}, $PM_{2.5}$, VOCs
 	
• **Reduce Energy Consumption Associated with Surface Transportation Vehicles**
  • Reduce excess fuel
  • Reduce energy consumption
	• **Increase Modal Shifts to Transit, Carpooling, and Vanpooling**
	
	• **Increase Purchases of Alternative Fuel Vehicles (AFVs)**
	
	• **Increase Vehicle Miles Traveled (VMT) of Alternative Fuel Vehicles**
	
	• **Increase Eco-Driving Awareness and Practice**
	
	• **Reduce Range Anxiety for Drivers of Electric Vehicles**
	
	• **Increase the Range of Electric Vehicles**
		• **Improve the Efficiency of the Transportation System**
		  • Reduce delay
		  • Improve the efficiency of the freeway (e.g., LOS)
		
		• **Improve Transit Operating Efficiency**
		
		• **Improve Freight Operating Efficiency**
			• **Reduce Crashes, Injuries, and Fatalities**
			  • Reduce total number of crashes on the freeway
			  • Reduce the number of injuries on the freeway
			  • Reduce the number of fatalities on the freeway

Next Steps

- The AERIS Program wants to hear your thoughts on the Dynamic Eco-Lanes Transformative Concept.
  - You can provide inputs and feedback using the AERIS IdeaScale Site (https://aeris.ideascale.com).
  - The AERIS Program will be conducting a Workshop on March 26th-27th to walk-through the Concept of Operations for the Dynamic Eco-Lanes Transformative Concept and other AERIS ConOps. To register for the workshop, visit: www.itsa.org/aeris2013

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