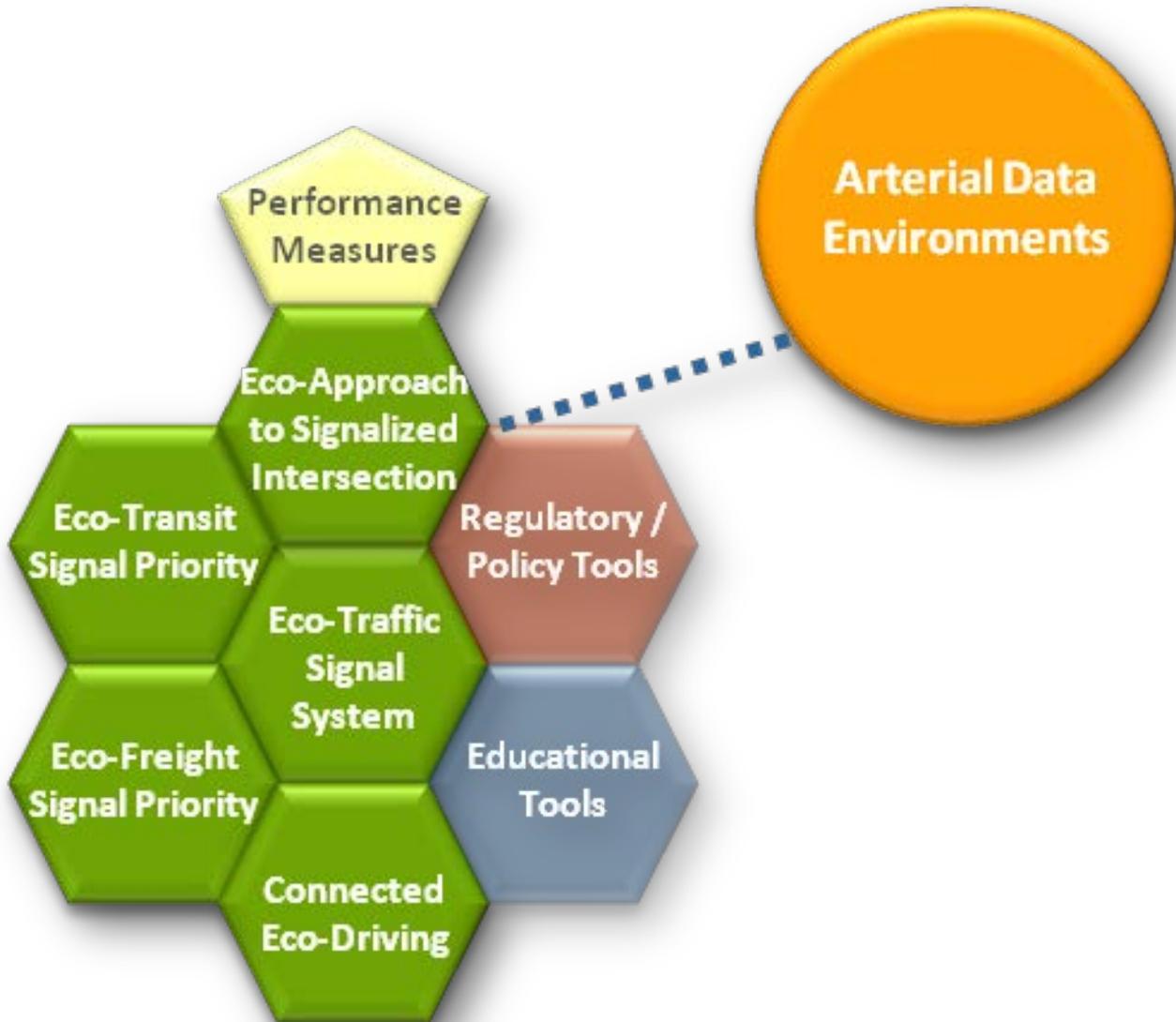




AERIS TRANSFORMATIVE CONCEPTS

"Cleaner Air Through Smarter Transportation"



Eco-Signal Operations

AERIS User Needs Workshop: March 14th-15th, 2012

Read-Ahead Packet

1 BACKGROUND

1.1 The AERIS Program

The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) is charged with the planning and execution of the ITS Program as authorized by Congress. The ITS JPO is part of the Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation (USDOT). This program encompasses a broad range of technologies that are applied to the surface transportation system. Under collaborative and transparent governance structure established for ITS JPO projects, the ITS JPO coordinates with and executes the program jointly in cooperation with all of the surface transportation modal administrations within the DOT to ensure full coordination of activities and leveraging of research efforts.

The USDOT is engaged in assessing applications that realize the full potential of connected vehicles, travelers and infrastructure to enhance current operational practices and transform future surface transportation systems management. This effort is a collaborative initiative spanning the Intelligent Transportation Systems Joint Program Office (ITS JPO), Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA). These agencies of the Federal Government work closely with the American Association of State Highway and Transportation Officials (AASHTO), who represent state transportation agencies across the country, as well as the numerous private sector interests (car manufacturers, technology companies, etc.) in working together in developing a nationwide system for ITS to be deployed in the future.

One foundational element of the ITS research efforts is the environment research area. The vision and objectives of the AERIS Program include:

VISION: *Cleaner Air Through Smarter Transportation*

OBJECTIVES: Investigate whether it possible and feasible to:

- Generate/capture environmentally-relevant real-time transportation data (from vehicles and the system)
- Use this environmental data to create actionable information that can be used by system users and operators to support and facilitate “green” transportation choices for all modes
- Assess whether doing these things yields a good enough environmental benefit to justify further investment by the USDOT

The AERIS Program recently concluded the first phase of their activity focused on foundational research and has moved into the second phase focused on Concept of Operations (ConOps) development, cost-benefit analysis, and modeling a portfolio of innovative environmental applications called Transformative Concepts.

1.2 What is a Transformative Concept?

Transformative Concepts are integrated, operational strategies that use vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data and communications to operate surface transportation networks and to help travelers make “green” travel choices with the aim of reducing the environmental impacts of transportation-related emissions and fuel consumption. Transformative Concepts consist of applications or technological solutions designed to ingest, process, and disseminate data in order to address a specific task. Transformative Concepts

emphasize combining applications that result in significant environmental benefits to surface transportation networks. Transformative Concepts also consider regulatory/policy and educational tools. The six (6) AERIS Transformative Concepts are:

- Eco-Signal Operations
- Eco-Lanes
- Dynamic Low Emissions Zones
- Support for Alternative Fuel Vehicle (AFV) Operations
- Eco-Traveler Information
- Eco-Integrated Corridor Management (ICM)

2 AERIS WORKSHOP BREAK-OUT SESSIONS

As the AERIS Workshop is intended to engage the community, participants should leave the workshop with a greater understanding of the AERIS Program and the AERIS Transformative Concepts. Additionally, each participant should feel that they have contributed to the development of the AERIS Transformative Concepts.

On the second day of the workshop, workshop participants will participate in Break-out Sessions for three of the AERIS Transformative Concepts: (1) Eco-Signal Operations, (2) Eco-Lanes, and (3) Dynamic Low Emissions Zones. The purpose of these break-out sessions is to elicit user needs for Concepts of Operations that will be developed for the Transformative Concepts. These Concepts of Operations will provide a blueprint that helps the AERIS Team and other stakeholders understand the various moving parts of the Transformative Concepts.

During the Break-out Sessions, a facilitator will be walking the workshop participants through a storyboard describing the AERIS Transformative Concept. At each step of the storyboard a facilitated discussion will take place around the following questions:

Break-out Session Questions

- (1) Who are the actors for each of the AERIS Transformative Concepts?
- (2) What applications are the actors responsible for?
- (3) What are the interactions between actors at each step of the Transformative Concept?
- (4) What type of information is exchanged between actors at each step of the Transformative Concept?

The following sections of this Read-Ahead Packet provide detailed information for the Transformative Concept, including the following information:

- Description of the AERIS Transformative Concept (Section 3.1)
- List and description of the applications that pertain to the AERIS Transformative Concept (Section 3.2)
- Actors that pertain to the AERIS Transformative Concept (Section 3.3)
- Communications Diagram (Section 3.4)
- Strawman Information Flow Diagram (Section 3.5)

3 ECO-SIGNAL OPERATIONS

3.1 Description

The Eco-Signal Operations Transformative Concept includes the use of connected vehicle technologies to decrease greenhouse gases (GHGs) and criteria air pollutant emissions on arterials by reducing idling, reducing the number of stops, reducing unnecessary accelerations and decelerations, and improving traffic flow at signalized intersections.

A foundational component of this concept uses wireless data communications among enabled vehicles and roadside infrastructure. This includes broadcasting signal phase and timing (SPaT) and Geometric Intersection Description (GID) data to vehicles. Upon receiving this information, in-vehicle systems will perform calculations to provide speed advice to the driver of the vehicle, allowing the driver to adapt the vehicle's speed to pass the next signal on green or to decelerate to a stop in the most eco-friendly manner.

This Transformative Concept also considers eco-traffic signal system applications. These applications would be similar to current adaptive traffic signal systems; however the application's objective function would be to optimize traffic signals for the environment using connected vehicle data. These applications collect data from vehicles, such as vehicle location, speed, GHG and other emissions data using connected vehicle technologies to determine the optimal operation of the traffic signal system.

Eco-Transit Signal Priority and Eco-Freight Signal Priority are also considered as part of this Transformative Concept. These applications allow either transit or freight vehicles approaching a signalized intersection to request signal priority. These applications consider the vehicle's location, speed, vehicle type (e.g., Alternative Fuel Vehicles) and associated GHG and other emissions to determine if priority should be granted. Other information, such as a transit vehicle's adherence to its schedule or number of passenger, may also be considered in granting priority.

3.2 Applications

Applications are technological solutions designed to ingest, process, and disseminate data in order to address a specific task. The Eco-Signal Operations Transformative Concept is composed of the following applications:

- Eco-Approach to a Signalized Intersection | This application uses SPaT data to provide driver recommendations that encourage "green" approaches to signalized intersections. The application leverages connected vehicle technology for dissemination of signal timing messages to in-vehicle systems. Upon receiving this information, in-vehicle systems calculate and provide speed advice to the driver of the vehicle, allowing the driver to adapt the vehicle's speed to pass the next signal on green or to decelerate to a stop in the most environmentally efficient manner.
- Eco-Traffic Signal System | This application interacts with traffic signal controller to adjust signal timing based on traffic and their associated GHG and other emissions and environmental conditions such as weather and atmospheric conditions. The application is similar to current adaptive traffic control systems; however the application's objective is to optimize traffic signals for the environment using connected vehicle data. The application collects data from vehicles, such as vehicle location, speed, GHG and other

emissions using connected vehicle technologies and determines the optimal operation of the traffic signal system.

- Eco-Transit Signal Priority | This application allows transit vehicles approaching a signalized intersection to request signal priority. The application considers criteria such as: the vehicle's location, speed, vehicle type (e.g., AFV), adherence to pre-determined transit schedule, and passenger load. The roadside application-specific unit and/or Traffic Management Center grants priority accordingly. If priority is granted, the traffic signal would either hold the green on the approach, while accounting for intersection performance, until the transit vehicle clears the intersection or the traffic signal reaches the maximum hold time, or advance the start of green to reduce the delay incurred by a transit vehicle. Determination for granting transit signal priority is based on multiple variables, with the objective of producing the least amount of emissions at the signalized intersection, corridor, or network.
- Eco-Freight Signal Priority | This application allows freight vehicles approaching a signalized intersection to request signal priority. The application considers the freight vehicle's location, speed, vehicle type (e.g., alternative fuel vehicles), load, schedule status, HAZMAT status, and associated GHG and other emissions to determine if priority should be granted. If priority is granted, the traffic signal would either hold the green on the approach until the freight vehicle clears the intersection or the traffic signal reaches the maximum hold time, or advance the start of green to reduce the delay incurred by a freight vehicle. Road grade is accounted for in the signal phase and timing. Granting of freight signal priority is based on multiple variables with the objective of producing the least amount of emissions at the signalized intersection, corridor, or network.
- Connected Eco-Driving | This application provides individual drivers (i.e., personal vehicles, transit, freight) with eco-driving information with the objective of promoting a driving style that lowers vehicle emissions. The Application provides drivers with real-time information (i.e., recommended speeds, accelerations) based on signal phase and timing of upcoming intersections, traffic, and road weather conditions so they can make decisions about their driving behavior. The Application also provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. The Connected Eco-Driving Application may also have vehicle systems implement the eco-driving tactics (i.e., change gears, switch power sources, or reduce speed in an eco-friendly manner as the vehicle approaches a traffic signal).

3.3 Actors

For a Transformative Concept to operate, interactions need to take place between actors. Actors represent roles played by human users, external hardware or software, a center, or a vehicle. For the purpose of this workshop, actors do not necessarily represent a specific physical entity, but merely a particular facet (i.e., “role”) of some entity that is relevant to the specification of its associated use cases. Additionally, a single physical entity (i.e., a traffic management center) may play the role of several different actors and, conversely, a given actor may be played by multiple different instances. For example, a traffic management center may play the traffic management and toll administration roles. While it plays multiple roles, the traffic management center is a single physical entity. Conversely, there is likely more than one traffic management center in a region or a state.

Descriptions of the actors specific to the Eco-Signal Operations Transformative Concept are provided below. These descriptions were taken from the National ITS Architecture. Actors are categorized into four areas: (1) centers, (2) vehicles, (3) travelers, and (4) roadside.

Centers

- Traffic Management | The Traffic Management actor monitors and controls traffic and the road network, including the *control of traffic signals*. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. This actor communicates with the Roadway actor to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status (e.g., traffic signals). This actor coordinates with the Maintenance and Construction Management actor to maintain the road network and coordinate and adapt to maintenance activities, closures, and detours. Incidents are detected, verified, and incident information is provided to allied agencies, drivers (through Roadway actor highway advisory radio and dynamic message signs), and information service providers. This actor also manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters. The Traffic Management actor supports high occupancy vehicle (HOV) lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The actor communicates with other Traffic Management actors to coordinate traffic information and control strategies in neighboring jurisdictions.
- Emissions Management | The Emissions Management actor provides the capabilities for air quality managers to monitor and manage air quality. These capabilities include collecting emissions data from distributed emissions sensors within the Roadway actor, from Vehicle actors, and ingesting regional air quality data from external sources and sensors such as operated by the National Weather Service or the Environmental Protection Agency. These sensors monitor general air quality within each sector of the area and also monitor the emissions of individual vehicles on the roadway. The sector emissions measures are collected, processed, and used to identify sectors exceeding safe pollution levels. This information is provided to traffic management to implement strategies intended to reduce emissions in and around the problem areas. Emissions data associated with individual vehicles, supplied by the Roadway and Traffic Management actors, are also processed and monitored to identify vehicles that exceed standards. This actor provides any functions necessary to inform the violators and otherwise ensure timely compliance with

emissions standards. This actor may co-reside with the Traffic Management actor or may operate in its own distinct location depending on regional preferences and priorities.

Vehicles

- **Personal Vehicle** | The Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and environmentally efficient travel. Information services provide the driver with current travel conditions and the availability of services along the route and at the destination. Both one-way and two-way communications options, including 5.9 Gigahertz (GHz) band approved for DSRC use by the Federal Communications Commission (FCC), support a spectrum of information services. Route guidance capabilities assist in formulation of an optimal route and step by step guidance along the travel route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. Initial collision avoidance functions provide 'vigilant co-pilot' driver warning capabilities. More advanced functions assume limited control of the vehicle to maintain safe headway. Ultimately, this actor supports completely automated vehicle operation through advanced communications with other vehicles in the vicinity and in coordination with supporting infrastructure actors. Pre-crash safety systems are deployed and emergency notification messages are issued when unavoidable collisions do occur.
- **Commercial Vehicle** | The Commercial Vehicle actor resides in a commercial vehicle and provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and environmentally efficient travel. Information services provide the driver with current travel conditions and the availability of services along the route and at the destination. Both one-way and two-way communications options, including 5.9 Gigahertz (GHz) band approved for DSRC use by the Federal Communications Commission (FCC), support a spectrum of information services. Route guidance capabilities assist in formulation of an optimal route and step by step guidance along the travel route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. Initial collision avoidance functions provide 'vigilant co-pilot' driver warning capabilities. More advanced functions assume limited control of the vehicle to maintain safe headway. Ultimately, this actor supports completely automated vehicle operation through advanced communications with other vehicles in the vicinity and in coordination with supporting infrastructure actors. Pre-crash safety systems are deployed and emergency notification messages are issued when unavoidable collisions do occur.

The Commercial Vehicle actor also provides two-way communications between the commercial vehicle drivers, their fleet managers, attached freight equipment, and roadside officials, and provides HAZMAT response teams with timely and accurate cargo contents information after a vehicle incident. This actor provides the capability to collect and process vehicle, cargo information from the attached freight equipment, and driver safety data and status and alert the driver whenever there is a potential safety or security problem. Basic identification, security and safety status data are supplied to inspection facilities and

roadside infrastructure at mainline speeds. In addition, the actor will automatically collect and record emissions, environmental data, mileage, fuel usage, and border crossings.

- **Transit Vehicle** | The Transit Vehicle actor resides in a transit vehicle and provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and environmentally efficient travel. Information services provide the driver with current travel conditions and the availability of services along the route and at the destination. The types of transit vehicles containing this actor include buses, paratransit vehicles, light rail vehicles, other vehicles designed to carry passengers, and supervisory vehicles. Both one-way and two-way communications options, including 5.9 Gigahertz (GHz) band approved for DSRC use by the Federal Communications Commission (FCC), support a spectrum of information services. Route guidance capabilities assist in formulation of an optimal route and step by step guidance along the travel route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. Initial collision avoidance functions provide 'vigilant co-pilot' driver warning capabilities. More advanced functions assume limited control of the vehicle to maintain safe headway. Ultimately, this actor supports completely automated vehicle operation through advanced communications with other vehicles in the vicinity and in coordination with supporting infrastructure actors. Pre-crash safety systems are deployed and emergency notification messages are issued when unavoidable collisions do occur.

The Transit Vehicle actor also supports a traffic signal prioritization function that communicates with the roadside actor to improve on-schedule performance. Automated vehicle location functions enhance the information available to the Transit Management actor enabling more efficient operations.

Roadside

- **Roadway** | The Roadway actor includes the equipment distributed on and along the roadway that monitors and controls traffic and monitors and manages the roadway itself. Equipment includes traffic detectors, environmental sensors, *traffic signals*, highway advisory radios, dynamic message signs, CCTV cameras and video image processing systems, grade crossing warning systems, and freeway ramp metering systems. HOV lane management, reversible lane management functions, and barrier systems that control access to transportation infrastructure such as roadways, bridges and tunnels are also supported. This actor also provides the capability for environmental monitoring including sensors that measure road conditions, surface weather, and vehicle emissions. In adverse conditions, automated systems can be used to apply anti-icing materials, disperse fog, etc.
- **Connected Vehicle Roadside Equipment** | The Connected Vehicle Roadside Equipment actor includes the roadside equipment (RSE) units distributed on and along the roadway. These devices are capable of both transmitting and receiving data using dedicated short range communications (DSRC) radios, using the 5.9 Gigahertz (GHz) band approved for DSRC use by the Federal Communications Commission (FCC). The devices also support other wireless communications, such as cellular and Wi-Fi communications. RSE units support the appropriate Institute of Electrical and Electronics Engineers (IEEE) and Society of Automotive Engineers

(SAE) standards (IEEE 802.11p, IEEE 1609 family, and SAE J2735). The Connected Vehicle Roadside Equipment actor also includes local processing capabilities to support processing of data at the roadside.

- Roadside Charging Infrastructure | The Roadside Charging Infrastructure Actor includes roadside infrastructure deployed along the roadway that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables inductive charging of electric vehicles including cars, trucks, and buses. Roadside Charging Infrastructure supports static charging capable of transferring electric power to a vehicle parked in a garage or on the street and vehicles stopped at a traffic light. It also supports charging vehicles moving at highway speeds.

3.4 Communications Interconnect Diagram

Figure 1 shows the various actors and the interactions between them. This diagram has been adapted from the National ITS Architecture and categorizes actors into four categories: (1) centers, (2) travelers, (3) vehicles and (4) roadside. The pink rectangles in the diagram describe communications technologies and how these actors are connected. These communication technologies include:

- Wide area wireless communications
- Fixed point to fixed point communications
- Vehicle-to-vehicle (V2V) communications
- Infrastructure-to-vehicle (I2V) and vehicle-to-infrastructure (V2I) communications

Figure 1 has been adapted for the Eco-Signal Operations Transformative Concept. Actors and interconnects that are not relevant to the Transformative Concept have been 'grayed out'.

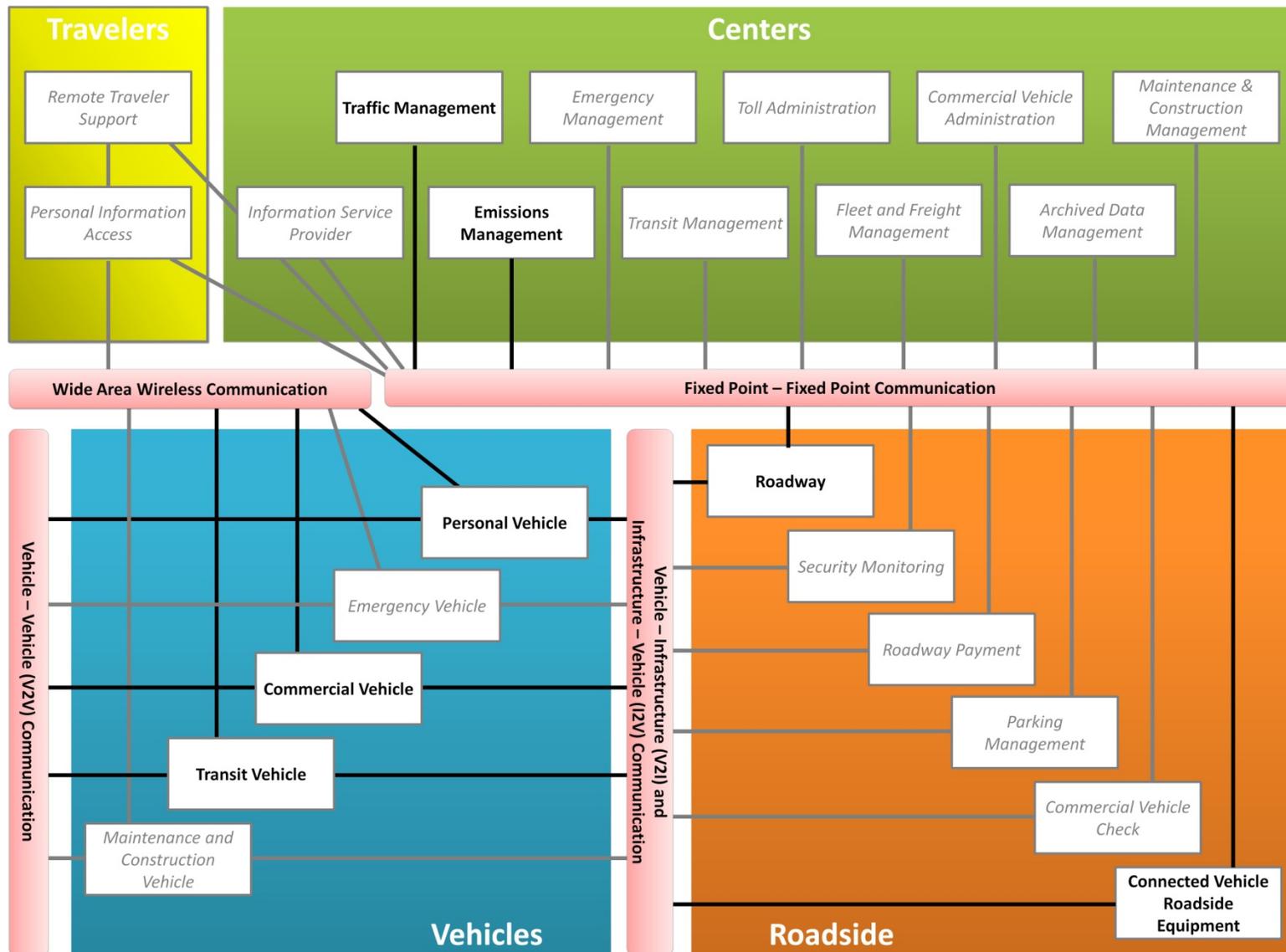


Figure 1 – Eco-Signal Operations Communications Interconnect Diagram

3.5 Strawman Information Flow Diagram

Information flow diagrams provide a graphical representation of the "flow" of information for a Transformative Concept for multiple applications at the same time. The information flow diagram depicts what kinds of information will be input and output from each actor, where the data will come from and go to, and where the data will be stored. It does not show information about the timing of processes, or information about whether processes will operate in sequence or in parallel (which is shown on a flowchart). In summary, the information flow diagrams show:

- The actors and interactions between actors for the Transformative Concepts
- The type of information that needs to be exchanged between actors to enable environmental applications and AERIS Transformative Concepts

Figure 2 depicts an example of an information flow being exchanged between actors. In this example, the actors are depicted using the green and orange boxes. The colors of these boxes correspond to the color coding in the Communication Interconnect Diagram. The gray boxes represent applications operated by that actor. In the example below, the 'traffic management' actor is controlling a traffic signal. This is denoted by the information flow labeled 'traffic signal control'. In return the traffic signal, or 'roadway' actor, provides traffic data (i.e., speed and volume data) back to the 'traffic management' actor.

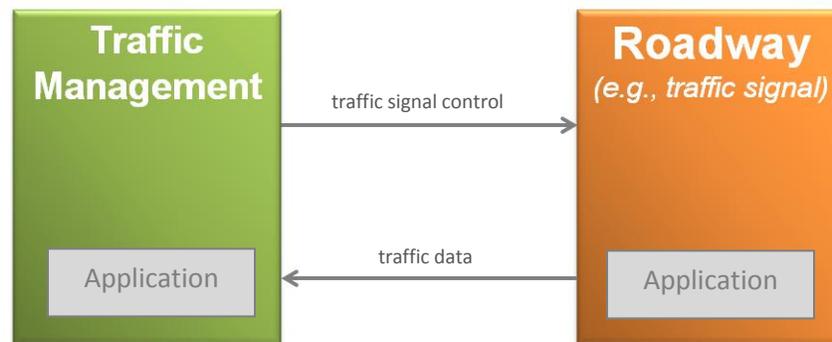


Figure 2 – Example Information Flow

Figure 3 depicts a *strawman* information flow diagram for the Eco-Signal Operations Transformative Concept. The actors are color-coded according to the categories in the Communications Interconnect Diagram. 'Travelers' are shown in yellow boxes, 'centers' in green boxes, 'vehicles' in blue boxes, and 'roadside' in orange boxes. Applications are shown within the actors in smaller gray boxes. Descriptions of these applications are provided in section 2.2. Arrows between actors depict information flows.

The purpose of the AERIS Transformative Concepts User Needs Workshop is to use these diagrams to begin thinking about the Transformative Concepts in more detail and to identify/verify:

- The actors as they pertain to the AERIS Transformative Concepts
- The applications for which that actor is responsible
- The interactions between actors at each step of the AERIS Transformative Concept
- The type of information exchanged between actors

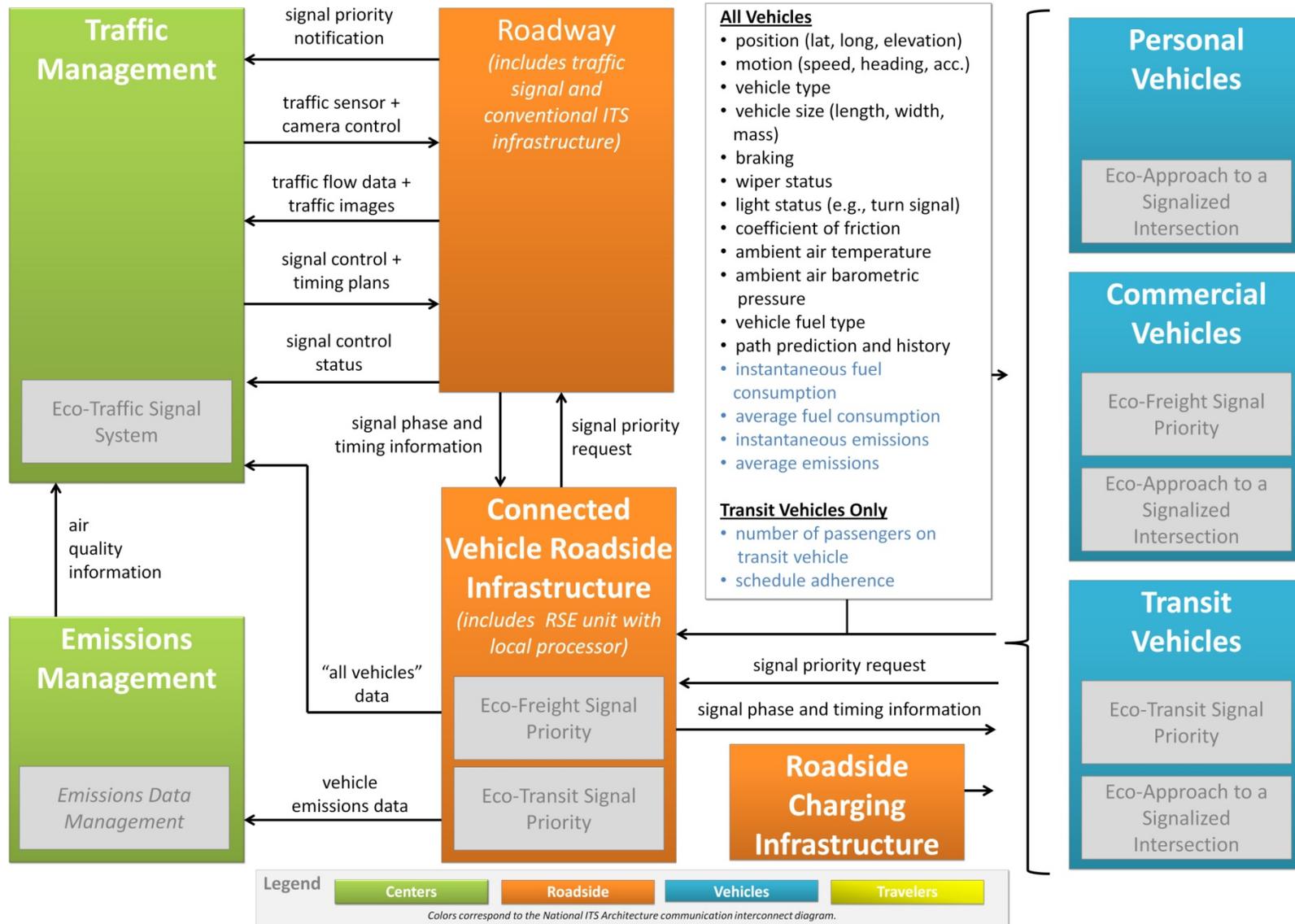


Figure 3 – Eco-Signal Operations Information Flow Diagram