AERIS OPERATIONAL SCENARIOS AND APPLICATIONS

ECO-SIGNAL OPERATIONS

- Eco-Approach and Departure at Signalized Intersections *(uses SPaT data)*
- Eco-Traffic Signal Timing *(similar to adaptive traffic signal systems)*
- Eco-Traffic Signal Priority *(similar to traffic signal priority)*
- Connected Eco-Driving *(similar to eco-driving strategies)*
- Wireless Inductive/Resonance Charging

ECO-LANES

- Eco-Lanes Management *(similar to managed lanes)*
- Eco-Speed Harmonization *(similar to variable speed limits)*
- Eco-Cooperative Adaptive Cruise Control *(similar to adaptive cruise control)*
- Eco-Ramp Metering *(similar to ramp metering)*
- Connected Eco-Driving *(similar to eco-driving)*
- Wireless Inductive/Resonance Charging

LOW EMISSIONS ZONES

- Low Emissions Zone Management *(similar to existing Low Emissions Zones)*
- Eco-Traveler Information Applications *(similar to ATIS)*

ECO-TRAVELER INFORMATION

- Connected Vehicle-Enabled Data Collection: Probe and Environmental Data
- Multimodal Traveler Information
- Eco-Smart Parking
- AFV Charging/Fueling Information, Reservations, and Payment
- Dynamic Eco-Routing
- Connected Eco-Driving – Gamified / Incentives-based Apps
- Gamified / Incentives-based Multimodal Traveler Information

ECO-INTEGRATED CORRIDOR MANAGEMENT

- Eco-ICM Decision Support System *(similar to ICM)*
- Eco-Signal Operations Applications
- Eco-Lanes Applications
- Low Emissions Zones Applications
- Eco-Traveler Information Applications
- Incident Management Applications

AERIS OPERATIONAL SCENARIOS

The Applications for the Environment: Real-Time Information Synthesis (AERIS) Research Program defined five Operational Scenarios and eighteen unique connected vehicle applications that sought to reduce fuel consumption and vehicle emissions. AERIS Operational Scenarios include: Eco-Signal Operations, Eco-Lanes, Low Emissions Zones, Eco-Traveler Information, and Eco-Integrated Corridor Management (Eco-ICM). Each Operational Scenario encompassed a set of applications which individually achieved environmental benefits. However, by strategically bundling the applications, the AERIS Program saw that the Operational Scenarios could achieve additional environment benefits above those of the individual applications. Many of these first-of-their-kind applications were innovative and transformative. The AERIS team created Concept of Operations (ConOps) documents for each of the five Operational Scenarios to guide analysis, modeling, simulation, and prototyping.

ECO-SIGNAL OPERATIONS

Eco-Signal Operations applications use connected vehicle technologies to decrease fuel consumption and emissions on arterials by reducing idling, reducing unnecessary stops, and improving traffic flow at signalized intersections. The Eco-Signal Operations Operational Scenario includes five applications: (1) Eco-Traffic Signal Timing, (2) Eco-Traffic Signal Priority, (3) Eco-Approach and Departure at Signalized Intersections, (4) Connected Eco-Driving, and (5) Wireless Inductive/Resonance Charging.

- **Eco-Approach and Departure at Signalized Intersections.** The Eco-Approach and Departure at Signalized Intersection application uses wireless data communications sent from a roadside equipment unit to connected vehicles to encourage "green" approaches to signalized intersections. The application, located in a vehicle, collects signal phase and timing (SPaT) and MAP messages using vehicle-to-infrastructure (V2I) communications and data from nearby vehicles using vehicle-to-vehicle (V2V) communications. Upon receiving these messages, the application performs calculations to determine the vehicle's optimal speed to pass the next traffic signal on a green light or to decelerate to a stop in the most eco-friendly manner. Speed recommendations may be provided to the driver using a driver-vehicle-interface (DVI) or provided to the vehicle systems that support automated longitudinal control capabilities.
- **Eco-Traffic Signal Timing.** The Eco-Traffic Signal Timing application's objective is to optimize the performance of traffic signals for the environment. The application collects data from vehicles, such as vehicle location, speed, and emissions data using connected vehicle technologies. It then processes these data to develop signal timing strategies focused on reducing fuel consumption and overall emissions at the intersection, along a corridor, or for a region. The application evaluates traffic and environmental parameters at each intersection in real-time and adapts so the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact.
- **Eco-Traffic Signal Priority.** The Eco-Traffic Signal Priority application allows either transit or freight vehicles approaching a signalized intersection to request signal priority. The application considers the vehicle's location, speed, vehicle type, and associated emissions to determine whether priority should be granted. Information collected from vehicles approaching the intersection, such as a transit vehicle's adherence to its schedule, the number of passengers on the transit vehicle, or weight of a truck may also be considered in granting priority. If priority is granted, the traffic signal would hold the green on the approach until the transit or freight vehicle clears the intersection.
- **Connected Eco-Driving.** The Connected Eco-Driving application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. Eco-driving advice includes recommended driving speeds, optimal acceleration, and optimal deceleration profiles based on prevailing traffic conditions, interactions with nearby vehicles, and upcoming road grades. The application also provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. Finally, the application may also include vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy (e.g., changes gears, switches power sources, or reduces its speed in an eco-friendly manner).

- **Wireless Inductive/Resonance Charging.** Wireless inductive/resonance charging includes 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 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 signal or a stop sign. It also supports dynamic charging of electric vehicle batteries when the vehicle is in motion.

ECO-LANES

The Eco-Lanes Operational Scenario includes dedicated lanes optimized for the environment, referred to as Eco-Lanes. Eco-Lanes are similar to managed lanes; however these lanes are optimized for the environment using connected vehicle data and can be responsive to real-time traffic and environmental conditions. These lanes would be targeted toward low emission, high occupancy, transit, and alternative fuel vehicles. Drivers would be able to opt-in to these dedicated eco-lanes to take advantage of eco-friendly applications such as eco-cooperative adaptive cruise control, connected eco-driving, and wireless inductive/resonance charging applications.

- **Eco-Speed Harmonization.** The Eco-Speed Harmonization application determines eco-speed limits based on traffic conditions, weather information, and emissions information. The purpose of speed harmonization is to change speed limits on links that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. Speed harmonization assists in maintaining flow, reducing unnecessary stops and starts, and maintaining consistent speeds, thus reducing fuel consumption, and emissions on the roadway. Eco-speed limits may be broadcast by roadside equipment units and received by on-board equipment units and/or posted on variable speed limit signs.
- **Eco-Cooperative Adaptive Cruise Control.** The Eco-Cooperative Adaptive Cruise Control application includes automated longitudinal vehicle control while considering eco-driving strategies. Expanding on existing adaptive cruise control (ACC) systems, which use radar and light detection and ranging (LIDAR) measurements to identify the location of the preceding vehicle, connected vehicle technologies can be used to collect the preceding vehicle's speed, acceleration, and location and feed these data into the vehicle's ACC. These data are transmitted from the lead vehicle to the following vehicle. This application allows following vehicles to use cooperative adaptive cruise control (CACC) aimed at relieving a driver from manually adjusting his or her speed to maintain a constant speed and a safe time gap from the lead vehicle. The Eco-CACC application also incorporates other information, such as road grade, roadway geometry, and road weather information.
- **Eco-Ramp Metering.** The Eco-Ramp Metering application determines the most environmentally efficient operation of traffic signals at freeway on-ramps to manage the rate of entering vehicles. This application collects traffic and environmental data to allow on-ramp merge operations that minimize overall emissions, including traffic and environmental conditions on the ramp and on the freeway upstream and downstream of the ramp. Using this information, the application determines a timing plan for the ramp meter based on current and predicted traffic and environmental conditions. The objective for this application is to produce timing plans that reduce overall emissions.
- **Connected Eco-Driving.** The Connected Eco-Driving application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. Eco-driving advice includes recommended driving speeds, optimal acceleration, and optimal deceleration profiles based on prevailing traffic conditions, interactions with nearby vehicles, and upcoming road grades. The application provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. The application may also include vehicle-assisted strategies

where the vehicle automatically implements the eco-driving strategy (e.g., changes gears, switches power sources, or reduces its speed in an eco-friendly manner).

- **Wireless Inductive/Resonance Charging.** Wireless inductive/resonance charging includes 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 wireless charging of electric vehicle batteries 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 signal or a stop sign. It also supports dynamic charging of electric vehicle batteries when the vehicle is in motion.

LOW EMISSIONS ZONES

Low Emissions Zones would be used to encourage decisions by travelers that help reduce transportation's negative impact on the environment. The Low Emissions Zones Operational Scenario envisions entities responsible for the operations of the transportation network to have the ability to define geographic areas that seeks to restrict or deter access by specific categories of high-polluting vehicles into the area for the purpose of improving the air quality within the geographic area. Alternatively, the Operational Scenario may incentivize traveler decisions that are determined to be environmentally friendly such as the use of alternative fuel vehicles or transit. Low Emissions Zones in a connected vehicle environment would be similar to existing low emissions zones; however they would leverage connected vehicle technologies allowing the systems to be more responsive to real-time traffic and environmental conditions (e.g., Code Red Air Quality Day, special event, etc.)

- **Low Emissions Zone Management.** This application supports the operation of a Low Emission Zone that is responsive to real-time traffic and environmental conditions. The application uses data collected from vehicles using connected vehicle technologies and from roadside equipment as input to the system. The Low Emissions Zone Management application supports the geo-fencing of a cordon that may be scalable and moveable (e.g., created for a day, removable, flexible in its boundaries) and would be less dependent on conventional intelligent transportation systems (ITS) infrastructure. The application would establish parameters including the types of vehicles permitted to enter the zone, exemptions for transit vehicles, emissions criteria for entering the zone, fees or incentives for vehicles based on emissions data collected from the vehicle, and geographic boundaries for the low emissions zones. The application would also include electronic toll collection functions that support payments of fees or collection of incentives for registered vehicles.
- **Eco-Traveler Information Applications.** Applications included in the Eco-Traveler Information Operational Scenario apply. Eco-Traveler Information Applications provide pre-trip and en-route traveler information about the Low Emissions Zones. This includes information about the geographic boundaries of the low emissions zones, criteria for vehicles to enter the Low Emissions Zones, expected fees and incentives for their trip, and current and predicted traffic and environmental conditions within and adjacent to the zones. Traveler information messages may be provided to various personal devices and in-vehicle systems and used by travelers to adjust their departure time or select an alternate route. Another key component of these applications is providing travelers with transit and shared use mobility options to encourage mode shift. Parking information in the Low Emissions Zones or at parking lots outside of the zones may also be provided.

ECO-TRAVELER INFORMATION

The Eco-Traveler Information Operational Scenario is focused on providing traveler information that assists travelers in making decisions that reduce fuel consumption and vehicular emissions. The objective of traveler information is to provide the traveling public with information regarding available modes, optimal routes, and departure times in real-time either pre-trip or en-route. Research has shown that successful traveler information services can impact fuel consumption and vehicular emissions in various forms. For example, applications that assist drivers in determining their route selection, departure times to avoid traffic, and eco-driving guidance can reduce non-optimal driving and reduce emissions. Significant environmental benefits also exist from mode shifts (e.g., from a single occupancy vehicle to transit, bicycle, carpool, etc.). An open data/open source approach is intended to engage researchers and the private sector to spur innovation and environmental applications.

- **Connected Vehicle-Enabled Environmental Probe Data Collection.** The Connected Vehicle-enabled Environmental Probe Data Collection Application supports the collection of fuel consumption and emissions data from vehicles. Connected vehicle technologies allow fuel consumption and emissions data to be collected from vehicle systems or sensors located on the vehicle and wirelessly transmitted back to centers. Using these data, real-time air quality maps may be created for roadway segments, corridors, and urban areas. By developing these maps, operating entities would be able to identify segments of the transportation network where fuel is being wasted or segments of the network prone to poor air quality.
- **Multimodal Traveler Information.** Multimodal Traveler Information Applications provides pre-trip and en-route traveler information to travelers encouraging a more sustainable relationship between transportation and the environment. The application collects multimodal data from connected vehicles, crowdsourced data from smartphone apps, and data from other sources. Trip planning tools provide travelers with information about multimodal travel options including transit service, bike share options, and car share options. Various tools including location aware, wirelessly enabled mobile devices enable travelers to find information and make reservations for these multimodal and shared-use services. Additionally, applications provide travelers with real-time traffic conditions so that they can either plan to or dynamically adjust departure time and mode choices (e.g., use transit) or select an alternate route to avoid congestion or incidents.
- **Eco-Smart Parking.** Eco-Smart Parking Applications provide users with real-time location, availability, type (e.g., street, garage), and price of parking. These applications reduce time required for drivers to search for a parking space, thereby reducing vehicular emissions. Eco-Smart Parking applications also supports dynamic pricing or incentives for parking based on vehicle type. Pricing and incentives may serve a traffic demand management strategy helping to reduce vehicle miles traveled in an area, or incentivize travel by eco-vehicles. These applications also allow travelers to reserve parking spaces in advance, as well as pay for parking, using mobile devices and connected vehicle technologies. Eco-Smart Parking applications may be combined with other Eco-Traveler Information applications and services such as trip planning services and eco-routing applications to provide more complete traveler information services to travelers.
- **AFV Charging/Fueling Information, Reservations, and Payment.** Alternative Fuel Vehicle (AFV) Charging/Fueling Information, Reservations, and Payment Applications inform travelers of the range of

their AFV and provide locations and the availability of AFV charging and fueling stations. The application allows drivers to make reservations to use charging/fueling stations before they start their trip or while en-route. Additionally, the application supports electronic payment for fuel/energy using connected vehicle technologies. In a connected environment, the results from the application would be dependent upon real-time traffic data sent to the car from infrastructure as well as an assessment of a driver's past behavior impact on range—e.g., lead-foot, light-foot, etc. Real-time data collected from vehicles (collected using connected vehicle technologies) would be used to provide better estimates of traffic delays and arrival times at the destination. Additionally, the vehicle would also learn from the driver's behavior providing accurate estimates of the vehicle's range in real-time, thus reducing the driver's fear of being stranded.

- **Dynamic Eco-Routing.** The Dynamic Eco-Routing application determines the most eco-friendly route, in terms of minimum fuel consumption or emissions, for individual travelers. The application is similar to current navigation systems which determine routes based on the shortest path or minimum time. The application leverages connected vehicle data to determine the eco-routes based on historical, real-time, predicted traffic and environmental data as well as road type (e.g., arterial or freeway) and road grade. The Dynamic Eco-Routing application takes into account a variety of different data, including: real-time traffic information, road type, road grade, and others. The application not only provides the eco-route, but may also provide information on the recommended departure time to avoid congestion based on current and historical traffic conditions. Trip departure times can impact the fuel consumption due to heavy traffic that causes congestions and therefore results in inefficient driving and increased fuel consumptions.
- **Connected Eco-Driving – Gamified/Incentives-Based Applications.** Connected Eco-Driving – Gamified/Incentives-based Applications use advanced sensors, software, and telematics allowing vehicular systems to communicate information about the vehicle's performance directly to the driver—via the dashboard or wirelessly to a smartphone. Drivers receive eco-driving recommendations and post-trip feedback on their behavior adapted to them and to their vehicle's characteristics. These applications would leverage a social media component, where people can compete on leaderboards on how much fuel and emissions they save from practicing eco-driving strategies. Drivers would compete with other drivers, earn points, get a better "status", and/or receive incentives for eco-driving behavior.
- **Gamified/Incentives-Based Multimodal Traveler Information Applications.** This application allows travelers to opt-in to smartphone apps to earn points for based on their travel choices. Travelers would earn points for green transportation choices including travel during off-peak hours, transit usage, bike usage, etc. These applications would allow system operators to collect data from travelers on their traveling behavior, would allow app users to receive customized traveler information, and would leverage a social media component where people would compete on leaderboards on how much fuel and emissions they save from making green transportation choices. Travelers would compete with other travelers, earn points, get a better "status", and/or receive incentives. Demand management strategies are a key component of these applications as they aim to reduce travel demand. In general, the benefits of access management include improved movement of traffic, reduced crashes, and fewer vehicle conflicts. Demand management applications can offer cost-effective strategies that help to increase freeway capacities without investing in a new, or expanding upon the existing, infrastructure.

ECO-INTEGRATED CORRIDOR MANAGEMENT

The objective of Eco-Integrated Corridor Management (Eco-ICM) is to realize significant environmental improvements in the efficient movement of people and goods through integrated and proactive management of major multimodal transportation corridors. The Eco-ICM Operational Scenario seeks to build on the successes of previous ICM initiatives by considering how connected vehicle and other future technologies may support the integrated operation of a major travel corridor to reduce transportation-related emissions on arterials and freeways. Eco-ICM should be thought of as an extension to the existing ICM concept – with the difference being that Eco-ICM seeks to ensure that environmental data and performance measures are considered in making operational decisions including the implementation of environmentally-oriented operational strategies such as eco-traffic signal timing, eco-speed harmonization, eco-traveler information, and other strategies.

- **Eco-Integrated Corridor Management Decision Support System.** The Eco-Integrated Corridor Management Decision Support System (DSS) seeks to assist managers in the process of collaboratively managing a multimodal transportation network. The ICM DSS would support eco-capabilities to ensure that environmental objectives are considered when managing the transportation network for the purpose of reducing transportation's negative impact on the environment. In general, the ICM DSS and associated eco-capabilities support multimodal, transportation operational decision-making in real-time including reducing delay as well as reducing emissions and fuel consumption. The DSS would integrate multiple real-time data sources from a variety of systems – including arterial, freeway, transit, and other management systems. Expanding on existing ICM DSSs, the Eco-ICM DSS would also collect environmental, connected vehicle, and shared use mobility data. These data would be processed, modeled, and analyzed to support decisions for specific actions, strategies, and recommendations. Those strategies would support environmental (and other) objectives such as reducing emissions, reducing fuel consumption, and improving air quality.