Concept Development and Needs Identification for Intelligent Network Flow Optimization (INFLO)

Operational Concept Stakeholder Workshop

February 8, 2012

SAIC Delcan VirginiaTech Transportation Institute Northwestern University

Agenda

8:30 a.m. – 9:00 a.m.	Welcome and Introductions
9:00 a.m. – 9:15 a.m.	Goals and Objectives of the Study
9:15 a.m. – 9:45 a.m.	Summary of Findings from Research Analysis/Scan of Current Practice
9:45 a.m. – 10:00 a.m.	Stakeholder Contribution Expectations
10:00 a.m. – 10:15 a.m.	**BREAK**
10:15 a.m. – 12:00 noon	Open Group Discussion on Goals, Performance Measures, Transformative Performance Targets
12:00 p.m. – 1:30 p.m.	**LUNCH**

Agenda (cont.)

1:30 p.m. – 1:45 p.m.	Applications Overview and Breakout Group Discussion Format
1:30 p.m. – 3:00 p.m.	Concurrent Breakouts(
	(Discuss Application Scenarios for SPD-HARM, Q-WARN and CACC)
3:00 p.m. – 3:15 p.m.	**BREAK**
3:15 p.m. – 4:15 p.m.	Concurrent Breakouts
	(Discuss User Needs for SPD-HARM, Q-WARN and CACC)
4:15 p.m. – 4:45 p.m.	Full Group Debriefs of each Application Breakout
4:45 p.m. – 5:00 p.m.	Recap of Meeting, Next Steps and Conclusion

Introductions

- Name
- Organization
- Area of Expertise
- Meeting Expectations
- Webinar

Meeting Outcome

- To solicit input on goals, performance measures, transformative performance targets, scenarios and user needs for the INFLO bundle
- Document this input for incorporation into the Draft ConOps Document

DMA Program Background

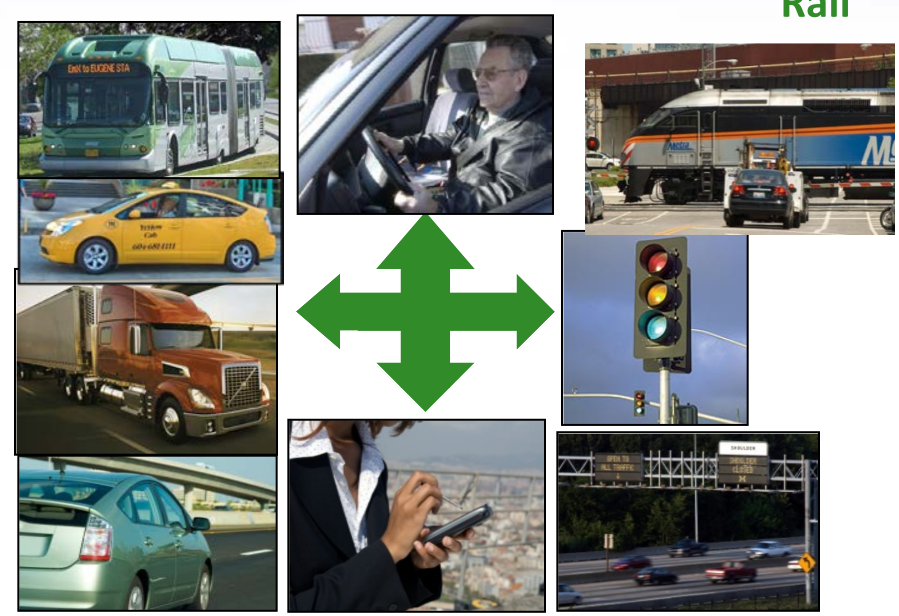
ITS Research: Multimodal and Connected

To Improve Safety, Mobility, and Environment

Research of technologies and applications that use wireless communications to provide connectivity:

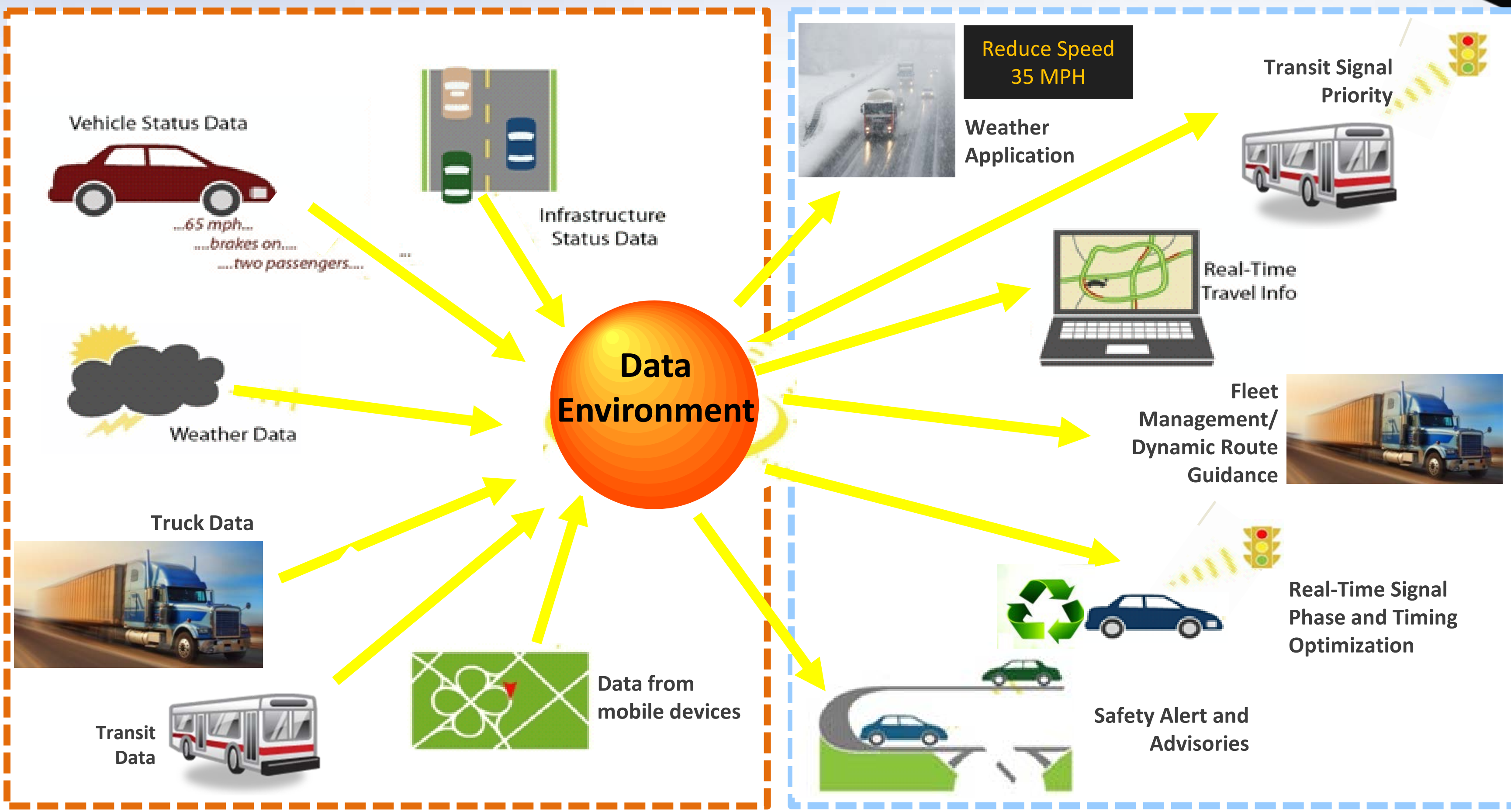
- Among vehicles of all types
- Between vehicles and roadway infrastructure
- Among vehicles, infrastructure and wireless consumer devices

FCC Allocated 5.9 GHz Spectrum (DSRC) for Transportation Safety



USDOT Mobility Program

Real-time Data Capture and Management | Dynamic Mobility Applications



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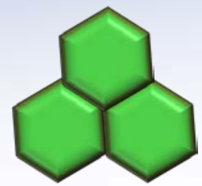
Dynamic Mobility Applications Program

Vision

- Expedite development, testing, commercialization, and deployment of innovative mobility application
  - maximize system productivity
  - enhance mobility of individuals within the system



Transformative Mobility Applications

(May have more impact when BUNDLED together)

Objectives

- Create applications using frequently collected and rapidly disseminated multi-source data from connected travelers, vehicles (automobiles, transit, freight) and infrastructure
- Develop and assess applications showing potential to improve nature, accuracy, precision and/or speed of dynamic decision
- Demonstrate promising applications predicted to significantly improve capability of transportation system
- Determine required infrastructure for transformative applications implementation, along with associated costs and benefits

Project Partners

- Strong internal and external participation
  - ITS JPO, FTA, FHWA R&D, FHWA Office of Operations, FMCSA, NHTSA, FHWA Office of Safety

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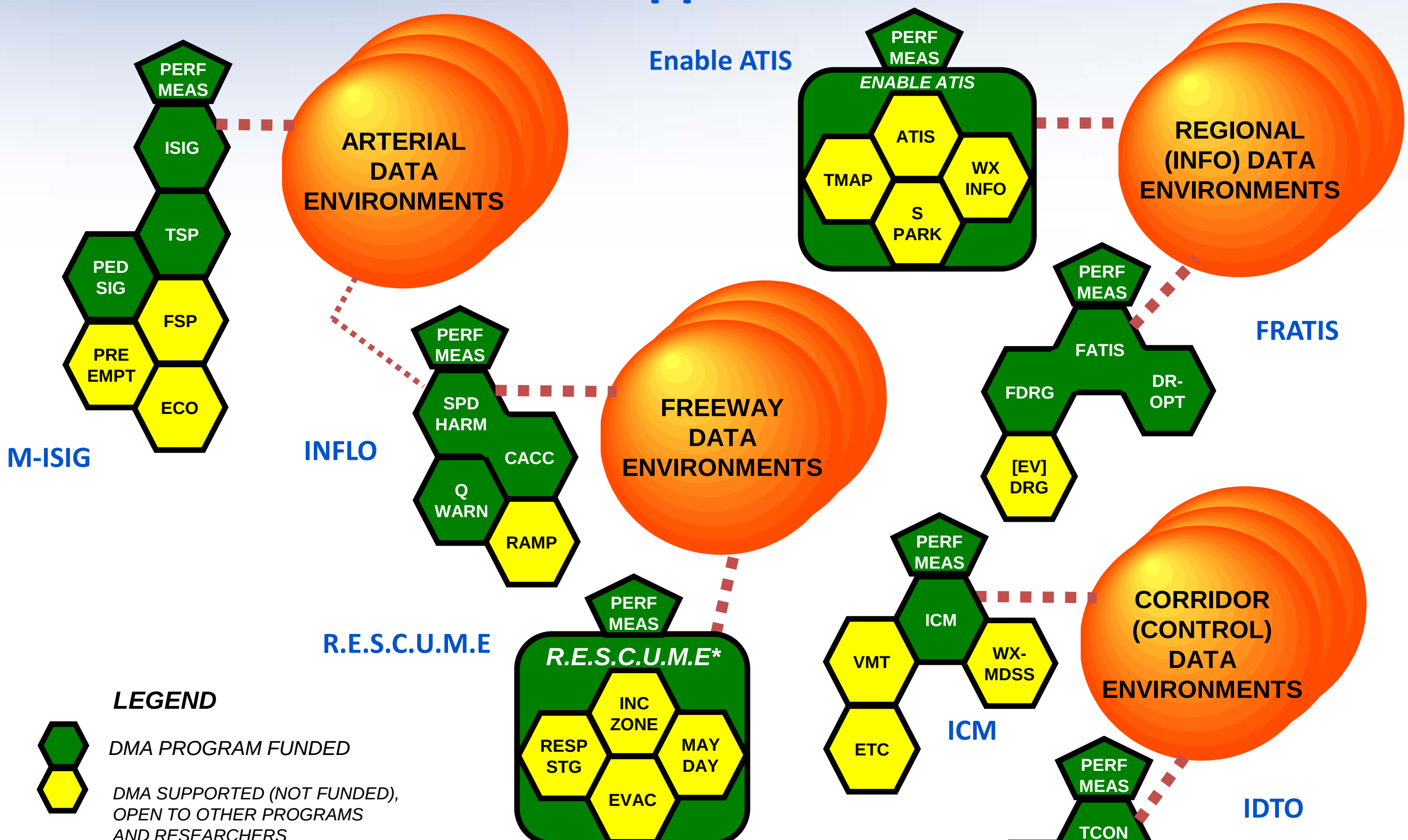
Transformative Application Bundles: Prioritization Approach

- USDOT solicited ideas for transformative applications
  - October 2010 - More than 90 submittals received
- Refine concepts to a manageable set of consolidated concepts (30)
  - Consolidated concepts used in variety of exercises at Mobility Workshop, 11/30-12/1/10 and with other stakeholder groups

DMA Program Summary

93 ideas → 30 applications → 7 bundles



**JOINTLY FUNDED BY DMA AND PUBLIC SAFETY PROGRAMS*

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The INFLO Bundle

Intelligent Network Flow Optimization (INFLO) bundle of applications:

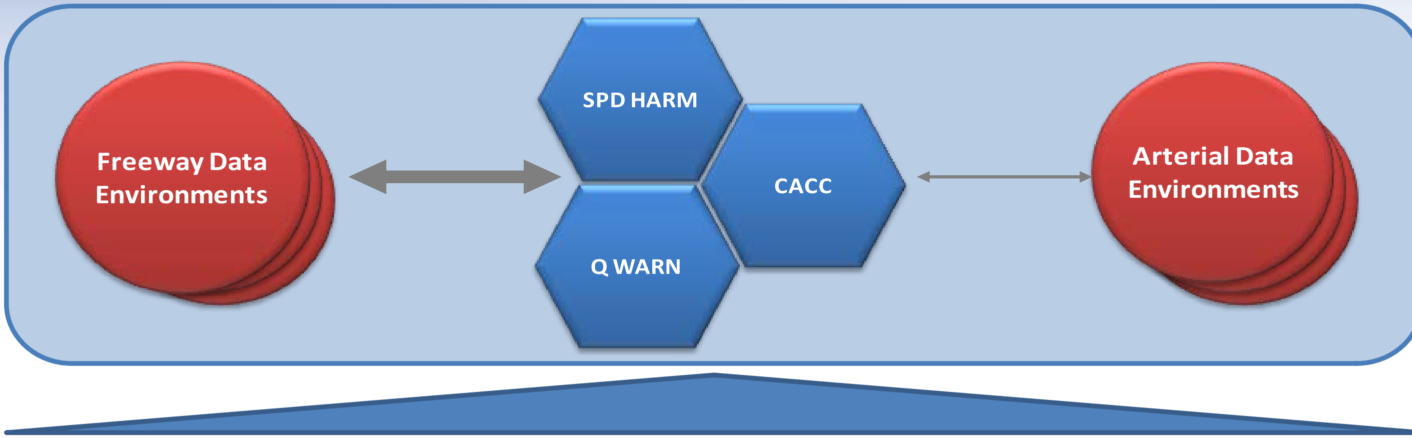
- Dynamic Speed Harmonization (SPD-HARM)
- Queue Warning (Q-WARN)
- Cooperative Adaptive Cruise Control (CACC)

Goals of INFLO

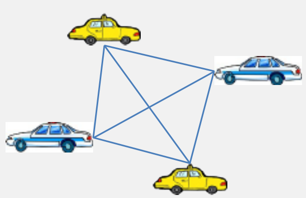
Utilize frequently collected and rapidly disseminated multi-source data drawn from connected travelers, vehicles, and infrastructure to:

- **Improve roadway throughput**
- **Reduce delay**
- **Improve safety**
- **Reduce emissions and fuel consumption**

INFLO Deployment Vision

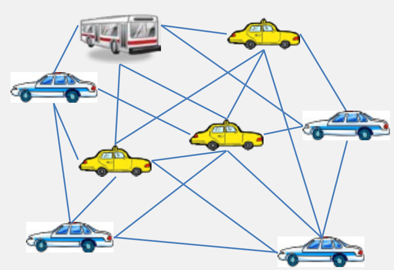


Near-Term
(Today – 2020)



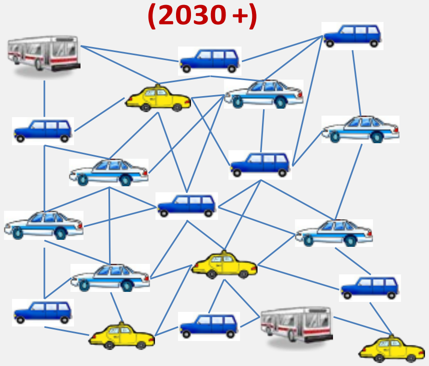
- Subset of DOT fleets, taxi fleets, etc.

Mid-Term
(2020 – 2030)



- 5% annual growth in fleet penetration

Ultimate
(2030 +)



- 100% vehicle penetration

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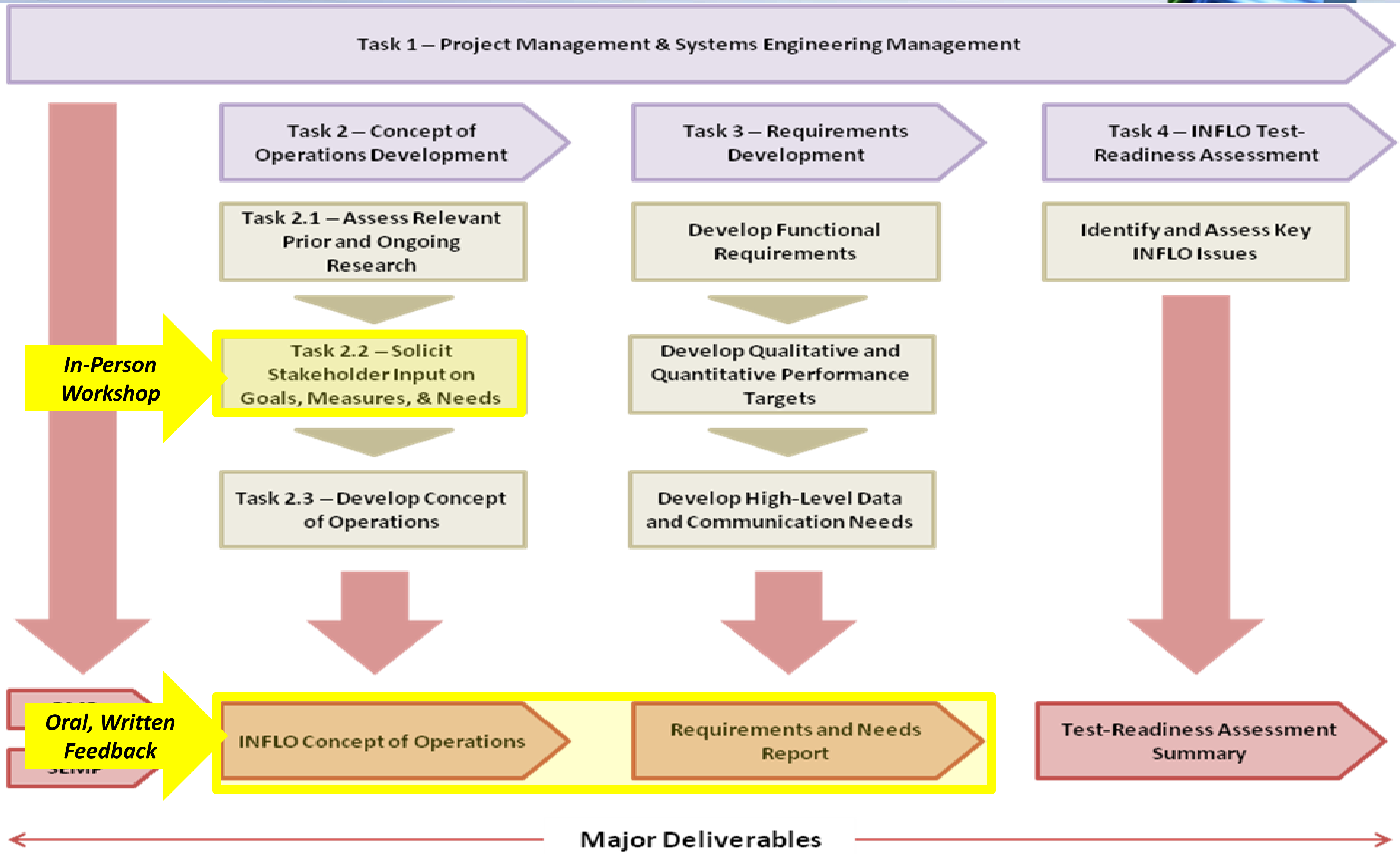
Goals and Objectives of the INFLO Study

1. Facilitate concept development and needs refinement for INFLO applications
2. Assess relevant prior and ongoing research
3. Develop functional requirements and corresponding performance requirements
4. Develop high-level data and communication needs
5. Assess readiness for development and testing

Project Tasks and Stakeholder Involvement



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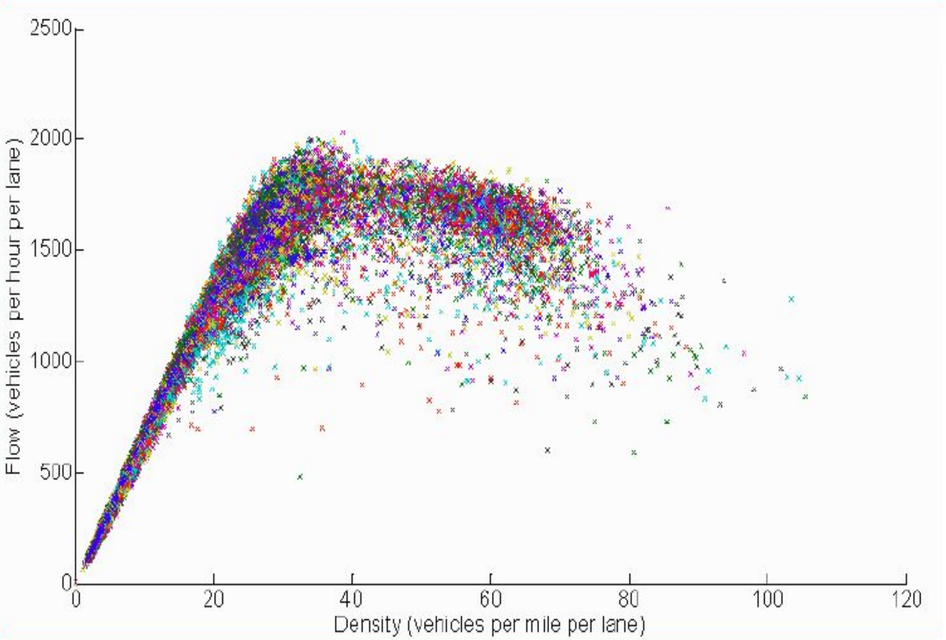
SPD-HARM: Concept Overview

Dynamic Speed Harmonization (SPD-HARM) aims to dynamically adjust and coordinate vehicle speeds in response to congestion, incidents, and road conditions to maximize throughput and reduce crashes.

- Reducing speed variability among vehicles improves traffic flow and minimizes or delays flow breakdown formation
- Utilize V2V and V2I communication to coordinate vehicle speeds
- Provide recommendations directly to drivers in-vehicle
- Recommend speeds by lane, by vehicle weight and size, by pavement traction

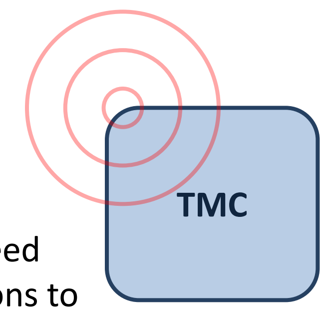


SPD-HARM Illustrative

4 Upstream vehicles implement (or alert drivers to) the recommended speed

1 Vehicles slowing down at recurrent bottleneck broadcast speed, location, etc.

3 TMC relays appropriate speed recommendations to upstream vehicles



2 TMC identifies impending congestion and initiates speed harmonization plan for upstream vehicles

SPD-HARM: Current Practice Overview

Typical speed harmonization implementation objectives:

- Speed management and safety
- Speed control under inclement weather condition
- Incident management
- Tunnel and bridge safety
- Flow and safety control along work zones

Solutions utilized:

- Variable speed limits
- Ramp metering

Limitations:

- Corridor-focused
- Minimal focus on mobility improvements
- Limited precision and granularity
- Enforcement and adherence issues

SPD-HARM: Key Deployments

Germany’s Autobahns: Speed Harmonization via VSL Signing

Implementation highlights:

- 200 km of roadway covered
- Loops for traffic flow conditions, weather (fog) detectors
- VISSIM microscopic traffic simulation to tune VSL algorithms
- Advisory (non-enforced) speed limits

Findings:

- 20-30% crash rate reduction in speed harmonization zones

Netherland’s A2 and A16: Speed Harmonization via VSL Signing

Implementation highlights:

- Loop detectors every 500 m; automatic incident detection
- Mandatory speed limits enforced by photo radar
- System revises posted speed limit every minute
- Objective to keep the posted and average actual speeds aligned

Findings:

- Increased traffic flow homogeneity (reduced speed variations)
- Less severe shockwaves and reduced average headways
- High compliance rates due to enforcement and public awareness of system

SPD-HARM: Key Deployments, *cont.*

United Kingdom's M42: Speed Harmonization via VSL Signing

Implementation highlights:

- Utilizes enhanced message signs, hard shoulder running, and automated enforcement
- Posted speed limit algorithm based on flow thresholds and between-lane speed differentials

Findings:

- *Undetermined*

Minnesota's I-35: Speed Harmonization via VSL Signing

Implementation highlights:

- Goal to manage deceleration and prevent rapid propagation of shockwaves
- Speed data from loops collected every 30 seconds
- Advisory (non-enforced) speed limits

Findings:

- Good compliance, without enforcement
- *Currently being evaluated*

SPD-HARM: Current Research

2011 V2I-Enabled Signal-Vehicle Cooperative Controlling System Study

Study highlights:

- IEEE conference paper examined the potential of producing an optimal schedule for traffic lights and an optimal speed for incoming cars to minimize stops utilizing V2I communication with downstream intersection controller
- Purpose is to minimize idling, reduce stop-then-start cycles, and improve throughput
- Controller communicates recommend speeds for approaching “smart” (i.e., V2I-enabled) vehicles

Findings:

- Using “moderate” levels of traffic demand for a 100-second period, when compared to the no-smart-car scenario, the smart car simulation produced:
  - 5% reduction in average delay
  - 33% reduction in average number of stops

SPD-HARM: Current Research, *cont.*

2010 California PATH Analysis of Combined VSL and Ramp Metering

Study highlights:

- Assess ability to defer or avoid traffic flow breakdowns for recurrent congestion at bottleneck locations by coordinating VSL and ramp metering
- How to implement the VSL feedback to the driver (e.g., via VSL signs or in-vehicle communication) to achieve the best driver response is a further study recommendation

Findings:

- Simulations achieved a significant reduction of travel delays and improvement in flow

2009 TxDOT Speed Limit Selection Algorithm Research

Study highlights:

- Multi-resolution simulation framework using VISSIM/VISTA
- Modeled segment of Mopac Expressway in Austin, TX
- Model was successful at achieving consistent flow harmonization

Findings:

- Achieving speed harmonization did not translate to increased throughput
- However, was successful at delaying breakdown formation

Q-WARN: Concept Overview

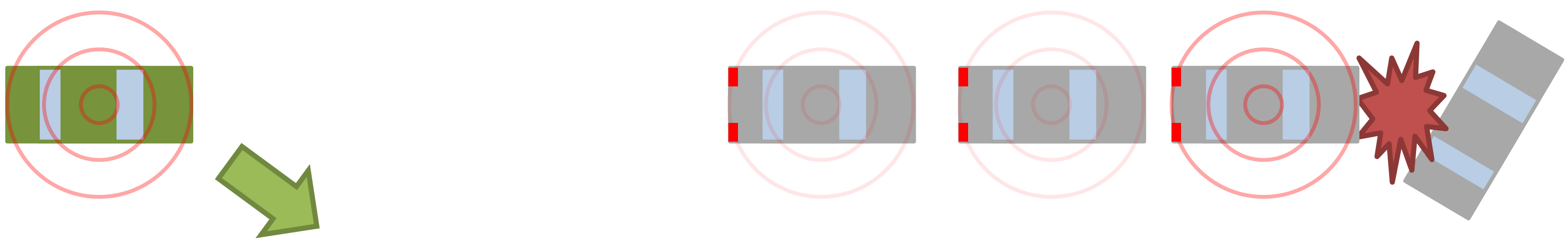
Queue warning (Q-WARN) aims to provide drivers timely warnings and alerts of impending queue backup.

- To reduce shockwaves and prevent collisions and other secondary crashes
- Predict location, duration and length of queue propagation
- Utilize V2V and I2V communication for rapid dissemination and sharing of vehicle information
  - E.g., position, velocity, heading, and acceleration of vehicles in the vicinity
- Allows drivers to take alternate routes or change lanes
- Applicable to freeways, arterials, and rural roads

Q-WARN Illustrative

3 Host Vehicle receives data and provides driver with imminent queue warning

1 Queue condition forms



2 Vehicles broadcast their rapid changes in speed, acceleration, position, etc.

4 Driver provided sufficient time to brake safely, change lanes, or even modify route

Q-WARN: Current Practice Overview

Typical queuing conditions:

- Exit ramp spillback
- Construction zone queues
- Fog (visibility)
- Border crossings

Solutions utilized:

- Infrastructure-based detection paired with static signs, variable speed signs/VMS, or flashers

Limitations:

- Static, infrastructure-based solutions limit range and scope of queue detection

Q-WARN: Key Deployments & Studies

***Illinois State Toll Highway Authority*:**

Adaptive Queue Warning

- Spillback detection for exit ramps and mainline
- Static sign-mounted flashers
- Tunable threshold algorithms

***Washington State I-405 ATM Feasibility Study*:**

ATM and Queue Warning

- Integrated with VSL speed harmonization effort
- Estimated 15% reduction in rear-end collisions (or 21 in a 3-year period)

Q-WARN: Other Deployments

Country	Queuing Condition	Technology
Australia	Exit ramp spillback	Loops, Variable speed signs (VSS) and variable message signs (VMS)
Belgium	Construction zone queues	Video detection, VMS panels, Trailer-mounted VMS
Canada	US border crossing near Niagara Border queues	Static signs with flashers
Finland	Fog – visibility and recurrent congestion	Loops, VSS, VMS
Japan	Recurrent congestion and Incident congestion	Ultrasonic detectors, VMS
New Zealand	Recurrent congestion	Static Signs
Norway	Special queue warning	VMS with flashers
Turkey	Recurrent congestion, Incident congestion, and Construction zone queues	Doppler radar, VSS, VMS
United Kingdom	Secondary collisions	Loops, VSS, VMS
State	**Queuing Condition**	**Technology**
Alabama	Fog – visibility	Forward-scatter visibility sensors, CCTV, VSS, VMS
California	Temecula -Exit ramp spillback	Static sign with pre-timed flashers for PM peak period
California	Highway 17 - Secondary collisions (near mountain pass)	Loops, Fog detectors, VMS
Florida	Construction zone queues	Video detection, Radar, Trailer-mounted VMS
Georgia	South Georgia Fog	VMS with preprogrammed messages
Illinois	Construction zone queues	Radar, Trailer-mounted VMS
Illinois	Tollway - Exit ramp spillback	Loops, Microwave detectors, Static signs with flashers
Indiana	Exit ramp spillback	Loops, Static signs with flashers
Minnesota	Recurrent congestion (at freeway lane drop), Rear-end collisions	Optical detectors, Static sign with flashers and a VMS
Missouri	Recurrent congestion, Rear-end collisions, Unfamiliar drivers	Static sign with flashers activated by time of day
New Jersey	Turnpike – Weather	VSS manually operated
North Carolina	Construction queues, Recurrent congestion, Rear-end collisions	Static signs with flashers
Oregon		
Pennsylvania	Construction zone queues, Sight distance limitations, Rear-end collisions	Infrared beams, Series of VMSs
South Carolina	Low Visibility warning	Forward-scatter visibility sensors, CCTV, VMS
Texas	San Antonio - Recurrent congestion, Rear-end collisions	Loops, VMSs
Texas	Fort Worth-Exit ramp spillback, Recurrent congestion, rear-end collisions	Video detection by TMC staff using cameras, Static Signs with flashers
Texas	Irving-Recurrent congestion, sight distance limitations, rear-end collisions	Series of Static signs
Utah	Fog – visibility	Visibility sensors, portable VMS
Virginia	Spillback at truck weigh stations	Loops, Electronic signs that tell truckers if the station is open

Q-WARN: Current Research

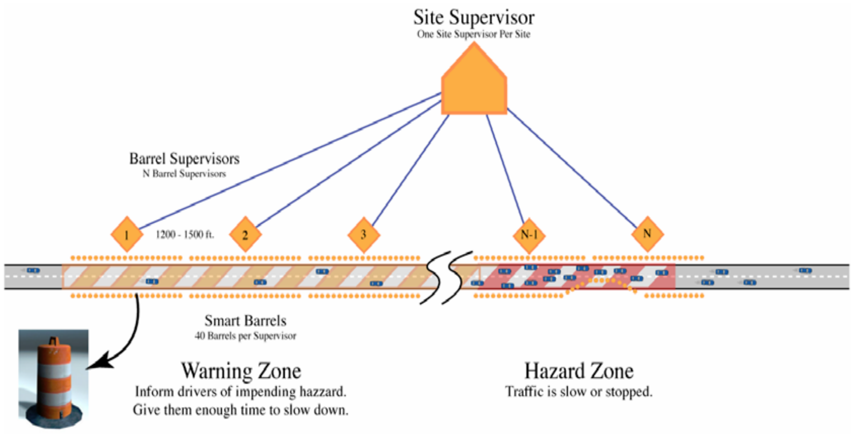
Smart Barrel Work Zone Safety Distributed Queue Warning System Evaluation

System highlights:

- Designed to adapt in real time to upstream of the work zone line
- The *smart barrel* contains a passive infrared speed sensor with an adjustable signaling system and communicates with a central controller

Findings:

- Drivers reported that the adaptive system was more helpful than static road signs
- Analysis of driving performance showed systematic improvement and suggested enhanced safety



Q-WARN: Current Research

2011 Vehicle Queuing & Dissipation Detection Using Two Cameras

Study highlights:

- IEEE conference paper examined the potential for detecting real-time queuing and dissipation by using two cameras, one fixed at the front of the stop line and the other a distance behind the stop line
- Experiments demonstrated ability to reliably detect the formation and dissipation of the queue under varying illumination conditions in real time
- 90% accuracy rate

Q-WARN: Current Research

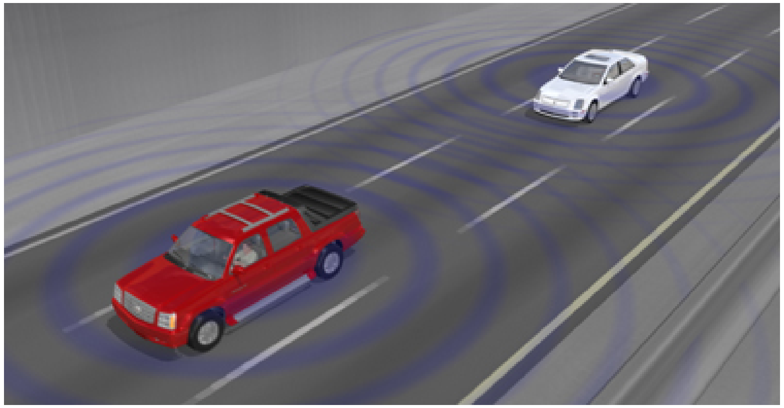
Wireless Long Haul Queue Warning Applications for Border Crossings

- Spillback detection for exit ramps and mainline
- Static sign-mounted flashers
- Tunable threshold algorithms

CACC: Concept Overview

Cooperative adaptive cruise control (CACC) aims to dynamically adjust and coordinate cruise control speeds among platooning vehicles to improve traffic flow stability and increase throughput.

- Closely linked with SPD-HARM to reduce stop-and-go waves
- Utilizes V2V and/or V2I communication to coordinate vehicle speeds and implement gap policy



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CACC Illustrative

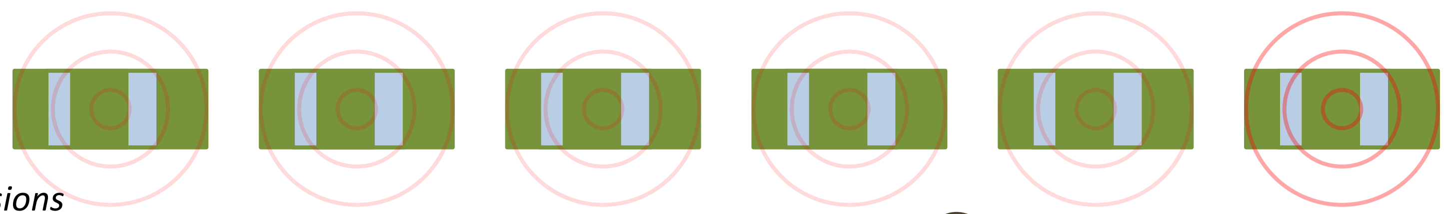
Without CACC:

- *Irregular braking and acceleration*
- *Longer headways*
- *Lower throughput*
- *Risk of rear-end collisions*

CACC Enabled:

1 Lead Vehicle broadcasts location, heading, and speed

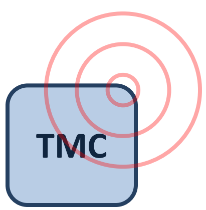
- *Coordinated speeds*
- *Minimized headways*
- *Higher throughput*
- *Reduced rear-end collisions*



2 CACC-enabled following vehicles automatically adjust speed, acceleration, and following distance

3 Any speed or acceleration perturbations by Lead Vehicle can be instantly accounted for by following vehicles utilizing V2V communication

4 TMC observes traffic flow and adjusts gap policy to manage road capacity



CACC: Current Practice Overview

Typical (non-cooperative) adaptive cruise control objectives:

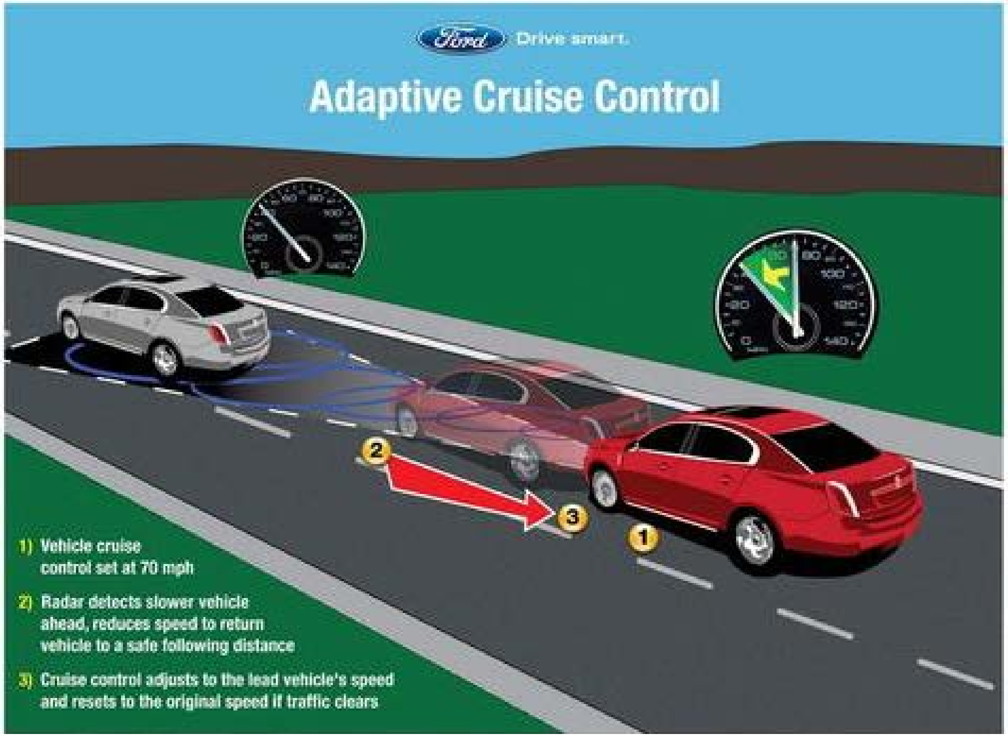
- Safety: maintaining safe following distances between vehicles

Solutions utilized:

- In-vehicle radar (or other surveillance)-based adaptive cruise control systems to automatically maintain minimum following distances

Limitations:

- Adaptive cruise control systems can look ahead only one car—cannot respond to the general traffic flow situation



Source: Ford Motor Company

CACC: Key Initiatives

2011 Grand Cooperative Driving Challenge (GCDC)

Competition description:

- Eleven teams from nine different countries competed to deliver the most effective cooperative vehicle-infrastructure system in pre-determined traffic
- Two scenarios tested:
  - **Urban Setting**. Platoon at traffic signal must merge and sync smoothly with another leading platoon
  - **Freeway Setting.** Lead vehicle of an existing platoon introduces acceleration disturbances; following vehicles must adapt.

Findings:

- Successful vehicle teams utilized detection including: radar, LIDAR, inertial sensors, GPS, and video-based scene understanding
- Also utilized 5.9GHz communication to coordinate lead and following vehicles
- Demonstrated that using existing technology, CACC-equipped vehicles could be successful at dampening shock waves, maintaining reduced headways, and improving throughput

CACC: Key Initiatives, *cont.*

UMTRI Study of the Effectiveness of ACC vs. CCC & Manual Driving

Study highlights:

- Study involved studies involved 36 drivers who drove an 88-km route during off-peak hours
- Compared velocity and braking of participants

Findings:

- No statistical difference was observed between velocities for ACC, CCC, and manual driving
- However, mean number of brake applications was found to be statistically different (5.8 applications for manual driving, 11.3 for CCC, and 7.4 for ACC)

CACC: Current Research

2011 California PATH CACC Human Factors Experiment

Experiment highlights:

- Experiment tested 16 naïve drivers' performance and choice-making in ACC and CACC environments
- Subjects adjusted following time gap settings according to preference in different traffic conditions

Findings:

- CACC simulations achieved significant reduction in travel delays and improvement in flow
- Drivers of the CACC system selected vehicle-following gaps that were half the length of the gaps they selected when driving the ACC system
- This result has favorable implications for adoption and use of CACC to improve highway capacity and traffic flow

CACC: Current Research, *cont.*

FHWA/University of Virginia Advanced Freeway Merge Assistance Study (Underway)

Study highlights:

- An Exploratory Advanced Research (EAR) Program project investigating Connected Vehicle-enabled cooperative merging strategies
- Key Connected Vehicle-enabled strategies being investigated include:
  - **Dynamic lane control:** to help identify available lane capacity around merge points so that merging and mainline traffic can more efficiently integrate
  - **Responsive metering:** to institute aggressive dynamic metering rates to take advantage of gaps for merging traffic
  - **Merge control:** cooperative merging techniques utilizing V2V communication

Applicability to CACC:

- Cooperative merging highly relevant to managing vehicle entry into and exit from platoons
- Minimizing vehicle entry and exit friction is key to maximizing the efficiency of a CACC platoon

CACC: Current Research, *cont.*

2011 Virginia Tech Transportation Institute Eco-CACC Study

Study highlights:

- Proposed a system that combines a predictive eco-cruise control system (ECC) with a car-following model to develop an eco-CACC system
- Model uses the Virginia Tech Comprehensive Power-based Fuel Model (VT-CPFM) to compute the optimum fuel-efficient vehicle control strategies

2002 Monte Carlo Simulation of System-Wide CACC Impacts

Study highlights:

- VanderWerf et al. conducted a Monte Carlo simulation study to quantify the system-wide impacts of a CACC system versus ACC and non-cruise control driving
- Study concluded that a significant headway reduction was possible with CACC and up to a 100% increase in capacity
- Strongly justifies dedicating a highway lane to CACC-equipped vehicles

CACC: Current Research, *cont.*

Additional relevant studies and research examined:

- *Coordination of Ad-hoc Groups Formed in Urban Environments* (Biddlestone, Redmill, and Ozguner)
- *Design and Experimental Evaluation of Cooperative Adaptive Cruise Control* (Ploeng, Scheepers, van Nunen, de Wouw, Nijmeijer)
- *Vehicle Automation in Cooperation with V2I and Nomadic Devices Communication* (Loper, a-Prat, Gacnik, Schomerus, Koster)
- *A New Concept of Brake System for ITS Platoon Heavy Duty Trucks and Its Pre-Evaluation* (Ishizaka, Hiroyuki, et al.)

SPD-HARM + Q-WARN + CACC: The Benefits of Bundling

The three INFLO applications are closely linked.

By deploying them in concert, the effectiveness of each is improved:

- SPD-HARM benefits Q-WARN by slowing and managing upstream traffic, thus reducing the risk of secondary collisions
- CACC benefits SPD-HARM by providing a mechanism for harmonizing traffic flow and reducing or mitigating acceleration variability
- Q-WARN benefits CACC by providing the platoon sufficient notification of an impending queue to effectively manage a response

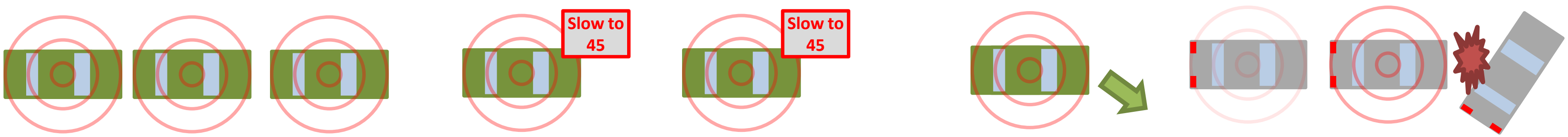
The following example illustrates how all three applications used in conjunction can help minimize the impact of a freeway incident on traffic flow…

Combined Q-WARN/SPD-HARM/CACC Illustrative

CACC

SPD-HARM

Q-WARN



4

CACC initiated for upstream traffic in order to maximize carrying capacity of the road as crash is cleared

3

Dynamic speed harmonization initiated for upstream traffic to reduce speed

2

Queue alert immediately provided to following vehicles to prevent secondary crashes

1

Freeway collision occurs and queue forms

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Stakeholder Contribution Expectations

- Input is being requested in five areas, for each application:
  1. Goals
  2. Performance Measures
  3. Transformative Performance Targets
  4. Scenarios
  5. User Needs

Stakeholder Contribution Expectations

Goals:

"High level objective describing the desired end result or achievement"

Performance Measures:

From the FHWA Office of Operations website: *"Performance measurement is the use of evidence to determine progress toward specific defined organizational objectives. This includes both quantitative evidence (such as the measurement of customer travel times) and qualitative evidence (such as the measurement of customer satisfaction and customer perceptions).*

Transformative Performance Targets:

"Mark we want to achieve for each performance measure"

Stakeholder Contribution Expectations

Example:

Goal = "Reduce Secondary Incidents"

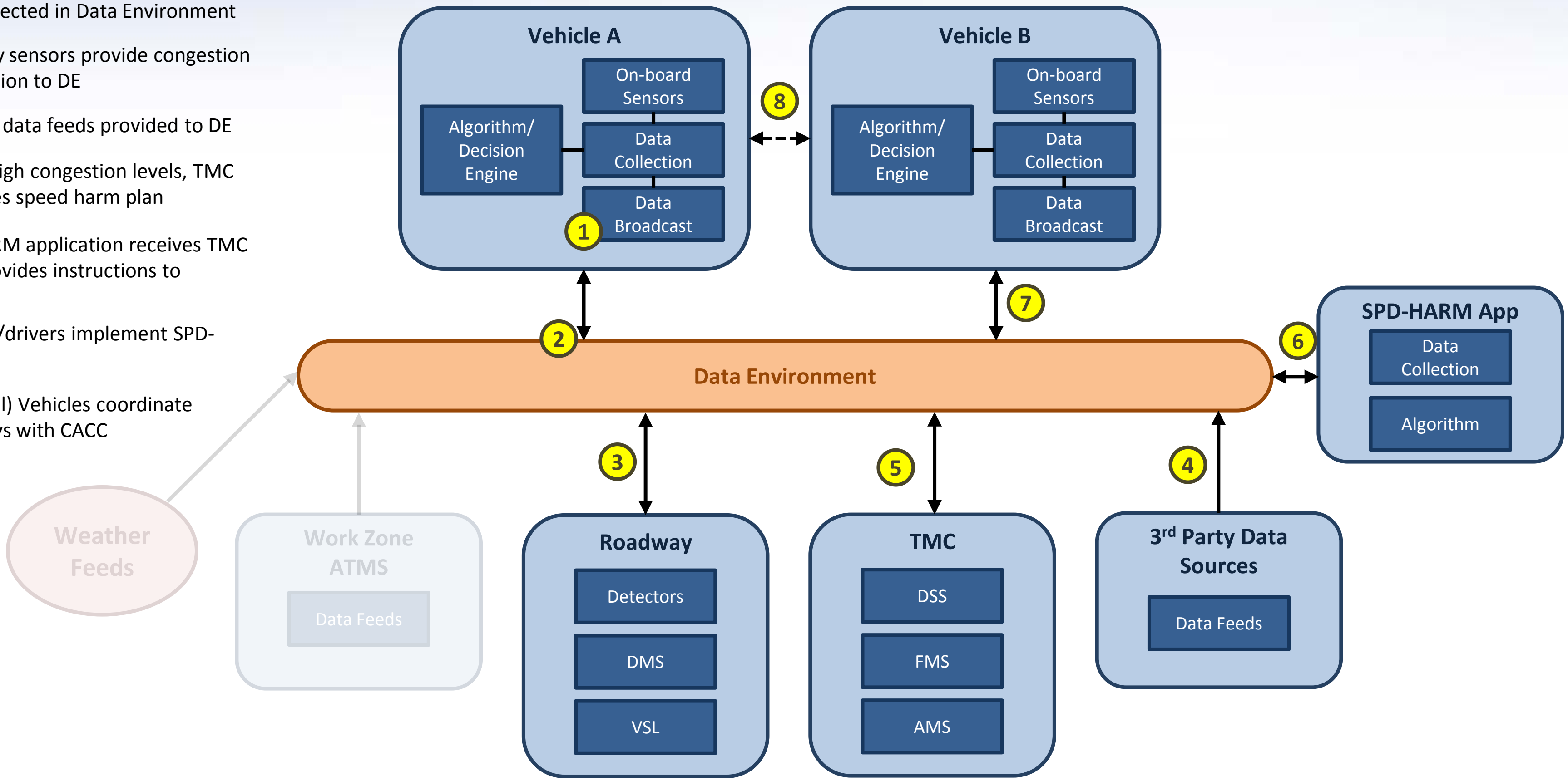
Performance Measure = "Secondary Incidents"

Transformative Performance Target = "40% Reduction in Secondary Incidents"

Stakeholder Contribution Expectations - Scenarios

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Roadway sensors provide congestion information to DE
4. 3rd party data feeds provided to DE
5. Due to high congestion levels, TMC generates speed harm plan
6. SPD-HARM application receives TMC plan, provides instructions to vehicles
7. Vehicles/drivers implement SPD-HARM
8. (Optional) Vehicles coordinate headways with CACC

SPD-HARM Congestion Management Scenario



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Stakeholder Contribution Expectations – User Needs

User Type	User Need	Description
Vehicle operator	Need the vehicle to be connected wirelessly to the SPD-HARM system	Vehicles should be wirelessly connected using Connected Vehicle or other conventional wireless technologies
Vehicle operator	Need to obtain specific traffic information from the vehicle or in-vehicle wireless devices	Information such as traffic flow, speed, acceleration/deceleration, weather, incidents or other information impacting traffic conditions should be pulled from the vehicle.
Vehicle operator	Need information on recommended or required speeds and lanes of travel should be provided to drivers	In order to enable speed harmonization, recommend maximum speeds as well as recommended lanes of travel will be provided to drivers within the vehicles.
Vehicles	Need to exchange traffic flow and traffic condition information from other vehicles	To enable true speed harmonization, communication with other nearby vehicles on the roadway will be required.
Roadway System	Need to obtain information from traditional roadway sensor systems, in near real time, to assess roadway conditions	To aid in speed harmonization, the SPD-HARM system should obtain traffic flow and speed information from existing sensors (Vehicle Detection Sensors) and other probe system sensors, if available

Agenda

8:30 a.m. – 9:00 a.m.	Welcome and Introductions
9:00 a.m. – 9:15 a.m.	Goals and Objectives of the Study
9:15 a.m. – 9:45 a.m.	Summary of Findings from Research Analysis/Scan of Current Practice
9:45 a.m. – 10:00 a.m.	Stakeholder Contribution Expectations
10:00 a.m. – 10:15 a.m.	**BREAK**
10:15 a.m. – 12:00 noon	**Open Group Discussion on Goals, Performance Measures, Transformative Performance Targets**
12:00 p.m. – 1:30 p.m.	**LUNCH**

SPD-HARM Goals

SPD-HARM Goals

1. Increase roadway throughput
2. Reduce roadway delay
3. Reduce or eliminate shockwaves
4. Diminished excessive speeds, for prevailing conditions
5. Reduce Speed Variability
6. Reduction in primary and secondary incidents

SPD-HARM Goals (cont.)

7. Improve Tunnel and Bridge Safety
8. Improve Speed Control in inclement weather
9. Improve safety control in work zones

SPD-HARM Performance Measures

Performance Measures for SPD-HARM

- Throughput
- Delay
- Primary Incidents
- Secondary incidents
- Emissions
- Speed Compliance
- Public Opinion
- Travel Time Reliability
- Uniform Lane Utilization

SPD-HARM
Transformative Performance Targets

Transformative Performance Targets for SPD-HARM

- 2% increase in throughput
- 25% reduction in primary incidents
- 35% reduction in secondary incidents
- 2% emissions reduction
- 75% speed compliance
- 70% of users provide positive opinion of the application
- 10% improvement in travel time reliability

Q-WARN Goals

Q-WARN Goals

1. Reduce incidents approaching construction zones
2. Reduce incidents approaching border crossings and other fixed queue points
3. Reduce incidents approaching traffic incident areas

Q-WARN Goals (cont.)

4. Reduce incidents approaching exit ramp spillover points
5. Reduce incidents approach adverse weather condition areas (e.g. Fog areas, ice areas)
6. Provide queue detection and warning capabilities without the use of intrusive devices (Detectors and DMS)

Q-WARN
Performance Measures

Performance Measures for Q-WARN

- Primary Incidents
- Secondary Incidents
- Shockwaves
- Capital Cost Reductions
- Recurring Cost Reductions

Q-WARN
Transformative Performance Targets

Transformative Performance Targets for Q-WARN

- 30% reduction in incidents approaching construction zones
- 30% reduction in incidents approaching border crossing and other fixed queue points
- 30% reduction in incidents approaching primary traffic incident locations
- 30% reduction in incidents approaching ramp spillover points
- 30% reduction in incidents approaching adverse weather locations
- 10% Reduce shockwave conditions in queue backup areas
- 75% Reduction in capital costs
- 75% Reduction in O&M costs

CACC Goals

CACC Goals

1. Reduce collisions
2. Reduced rear-end collisions
3. Increase roadway capacity
4. Reduce shockwaves
5. Increase traffic flow density and efficiency
6. Improve traffic smoothing
7. Improve vehicle/driver reaction time
8. Improve driver satisfaction

CACC
Performance Measures

Performance Measures for CACC

- Collisions
- Rear-end collisions
- Roadway capacity
- Throughput
- Traffic flow density and efficiency
- Speed Variability
- Driver satisfaction

CACC
Transformative Performance Targets

Transformative Performance Targets for CACC

- 25% reduction in average headway
- 15% increased roadway capacity
- 20% reduction in vehicle collisions/rear-end collisions
- 15% increased throughput
- 10% reduction in speed variability
- 70% of users provide positive opinion of the CACC application

Agenda (cont.)

1:30 p.m. – 1:45 p.m.	**Applications Overview and Breakout Group Discussion Format**
1:30 p.m. – 3:00 p.m.	Concurrent Breakouts(
	(Discuss Application Scenarios for SPD-HARM, Q-WARN and CACC)
3:00 p.m. – 3:15 p.m.	**BREAK**
3:15 p.m. – 4:15 p.m.	Concurrent Breakouts
	(Discuss User Needs for SPD-HARM, Q-WARN and CACC)
4:15 p.m. – 4:45 p.m.	Full Group Debriefs of each Application Breakout
4:45 p.m. – 5:00 p.m.	Recap of Meeting, Next Steps and Conclusion

Breakout Groups

- Two Breakout Group Sessions
  - Discuss Application Scenarios for SPD-HARM, Q-WARN and CACC – 1.5 Hours
  - Break
  - Discuss Application Scenarios for SPD-HARM, Q-WARN and CACC (1 hour)
- Return to Main Room at 4:15 for full group breakout discussions

Breakout Groups (Cont.)

- Assign Group spokesperson
- Record comments and discussions in breakout worksheets (in binder)
- Provide summary of results to group

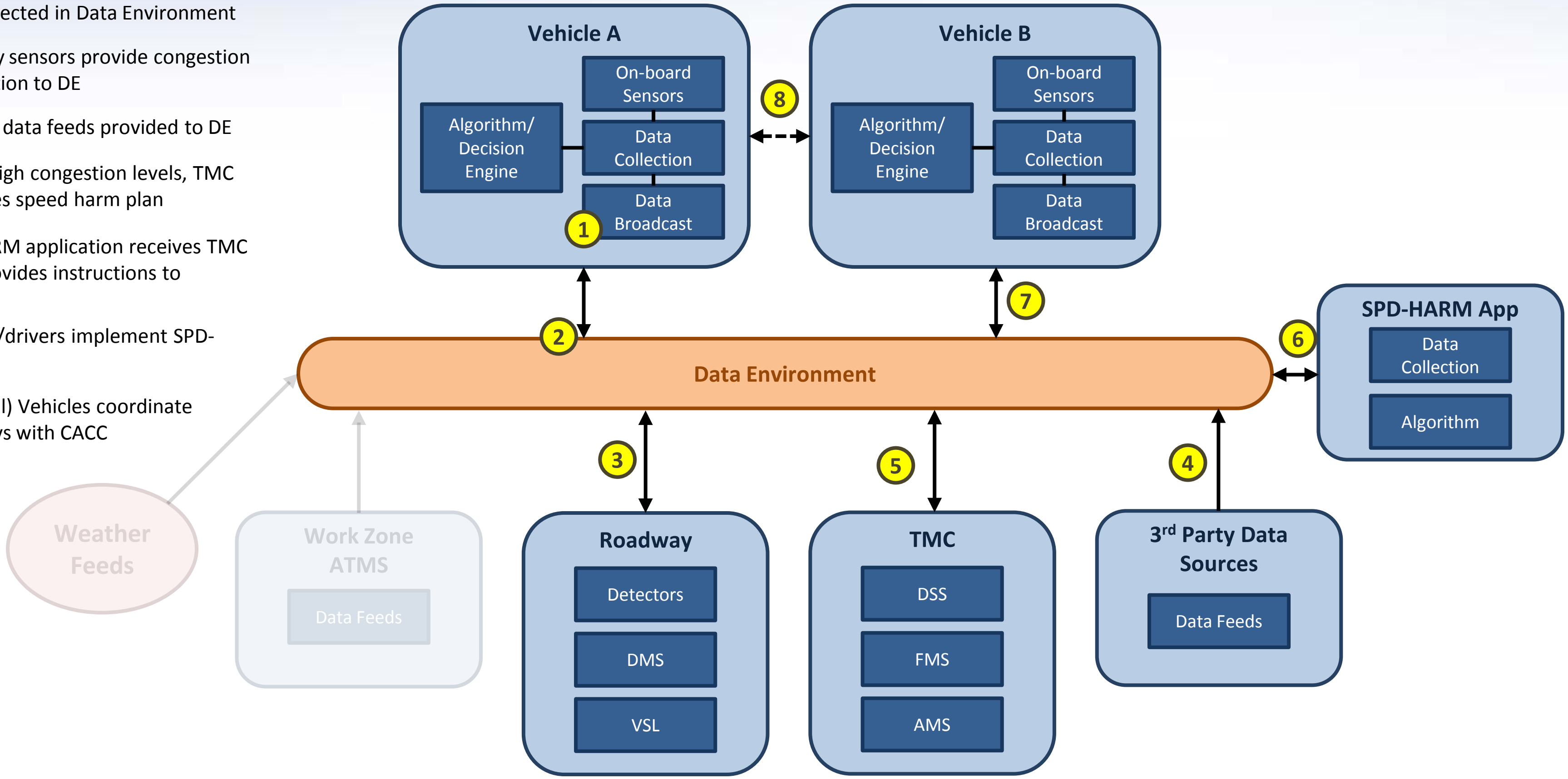
Concurrent Breakouts

(Discuss Application Scenarios for SPD-HARM, Q-WARN and CACC)

1:30 p.m. – 3:00 p.m.

SPD-HARM Scenario 1: Congestion Management

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Roadway sensors provide congestion information to DE
4. 3rd party data feeds provided to DE
5. Due to high congestion levels, TMC generates speed harm plan
6. SPD-HARM application receives TMC plan, provides instructions to vehicles
7. Vehicles/drivers implement SPD-HARM
8. (Optional) Vehicles coordinate headways with CACC



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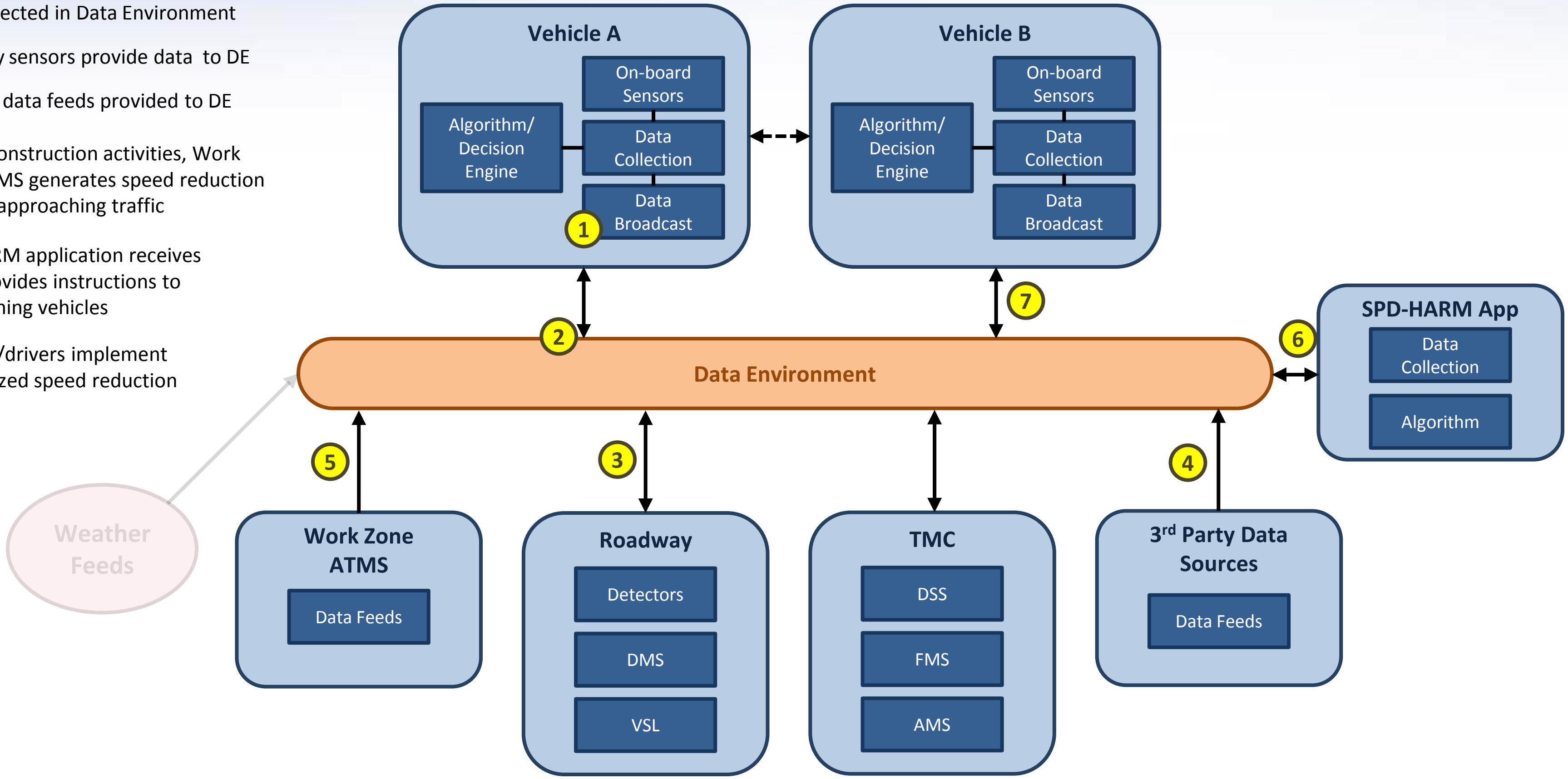
SPD-HARM Scenario 2: Work Zone

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Roadway sensors provide data to DE
4. 3rd party data feeds provided to DE
5. Due to construction activities, Work Zone ATMS generates speed reduction plan for approaching traffic
6. SPD-HARM application receives plan, provides instructions to approaching vehicles
7. Vehicles/drivers implement harmonized speed reduction



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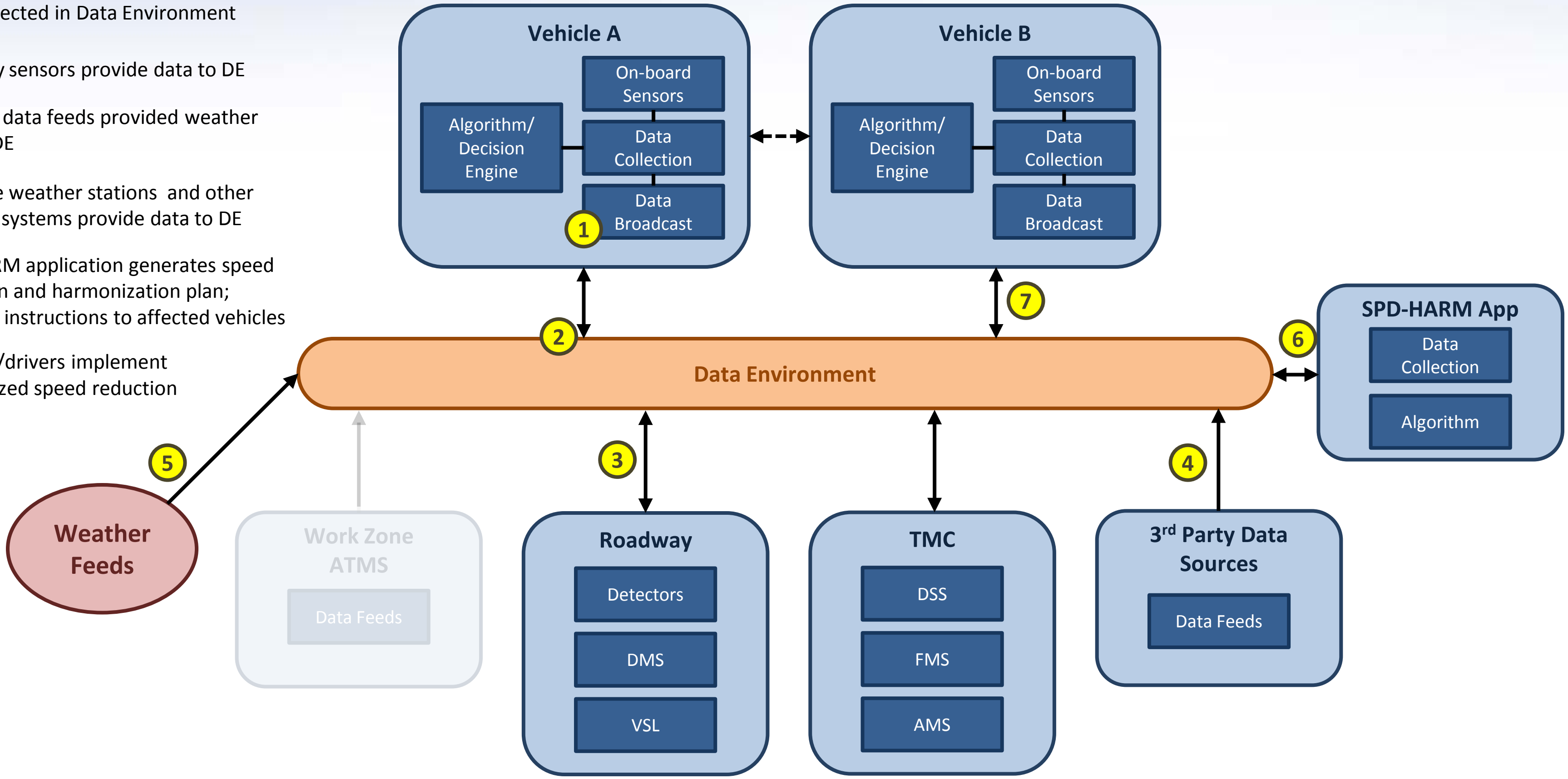
SPD-HARM Scenario 3: Weather Conditions

1. Vehicle broadcasts weather-related sensor information (windshield wiper activation, outside temp reading, etc.)
2. Data collected in Data Environment
3. Roadway sensors provide data to DE
4. 3rd party data feeds provided weather data to DE
5. Roadside weather stations and other weather systems provide data to DE
6. SPD-HARM application generates speed reduction and harmonization plan; provides instructions to affected vehicles
7. Vehicles/drivers implement harmonized speed reduction



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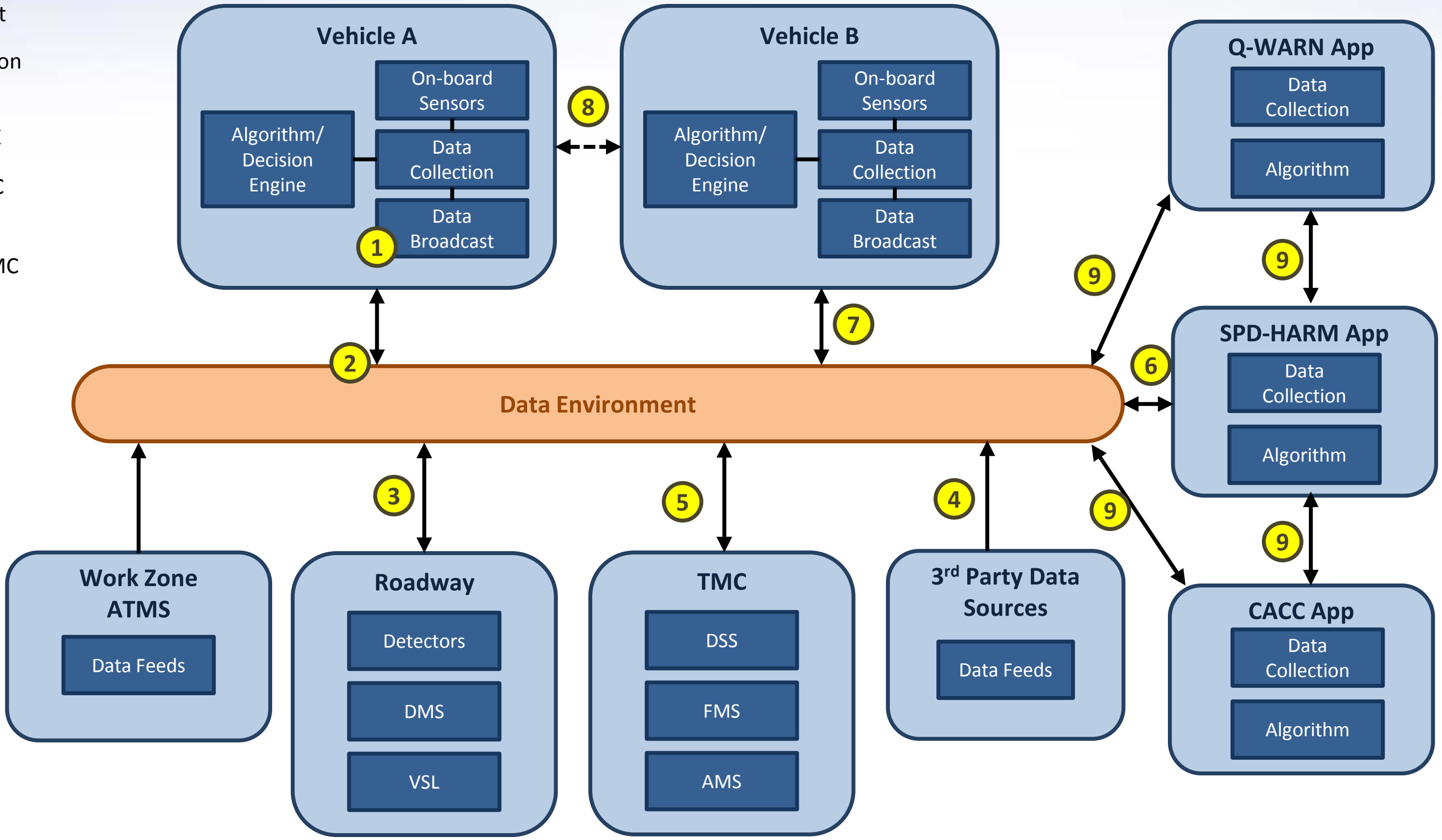
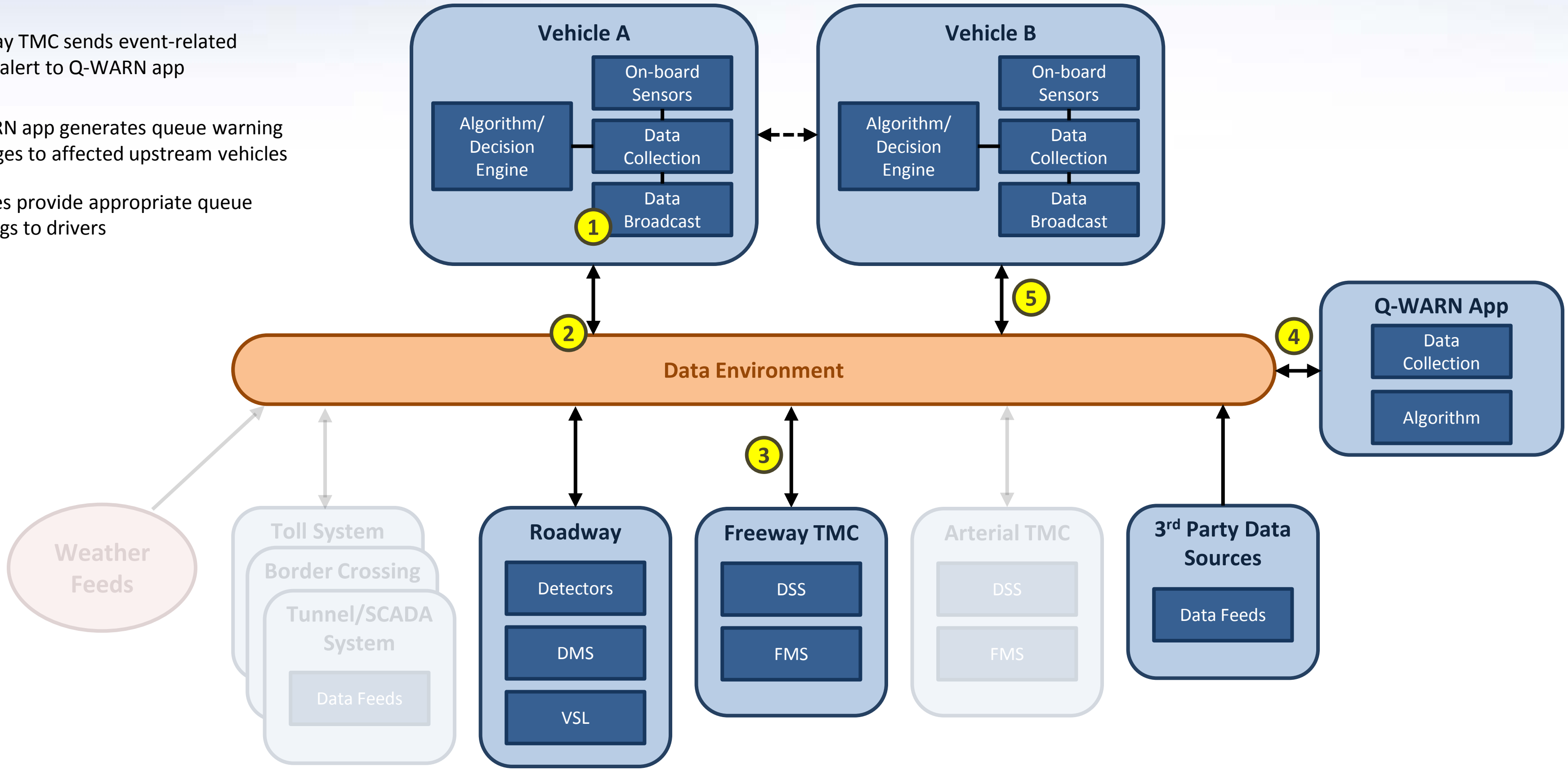
SPD-HARM Scenario 4: INFLO BUNDLE COMBINED

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Roadway sensors provide congestion information to DE
4. 3rd party data feeds provided to DE
5. Due to high congestion levels, TMC generates speed harm plan
6. SPD-HARM application receives TMC plan, provides instructions to vehicles
7. Vehicles/drivers implement SPD-HARM
8. Vehicles coordinate headways with CACC
9. INFLO Applications integrate for coordinated operation



Q-WARN Scenario 1: Event-Induced Queue

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Freeway TMC sends event-related queue alert to Q-WARN app
4. Q-WARN app generates queue warning messages to affected upstream vehicles
5. Vehicles provide appropriate queue warnings to drivers



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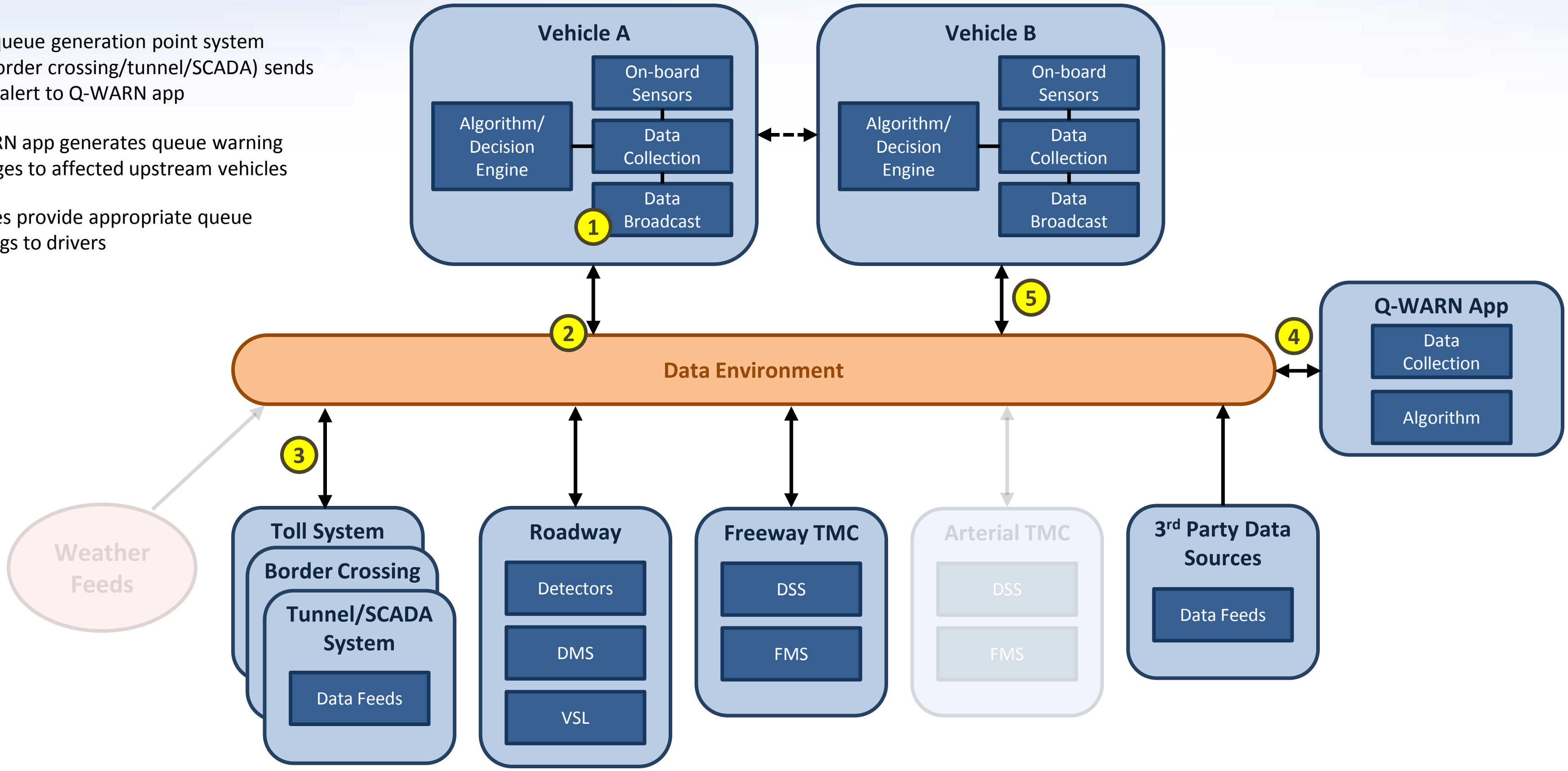
Q-WARN Scenario 2: Fixed Queue Generation Points

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Fixed queue generation point system (toll/border crossing/tunnel/SCADA) sends queue alert to Q-WARN app
4. Q-WARN app generates queue warning messages to affected upstream vehicles
5. Vehicles provide appropriate queue warnings to drivers



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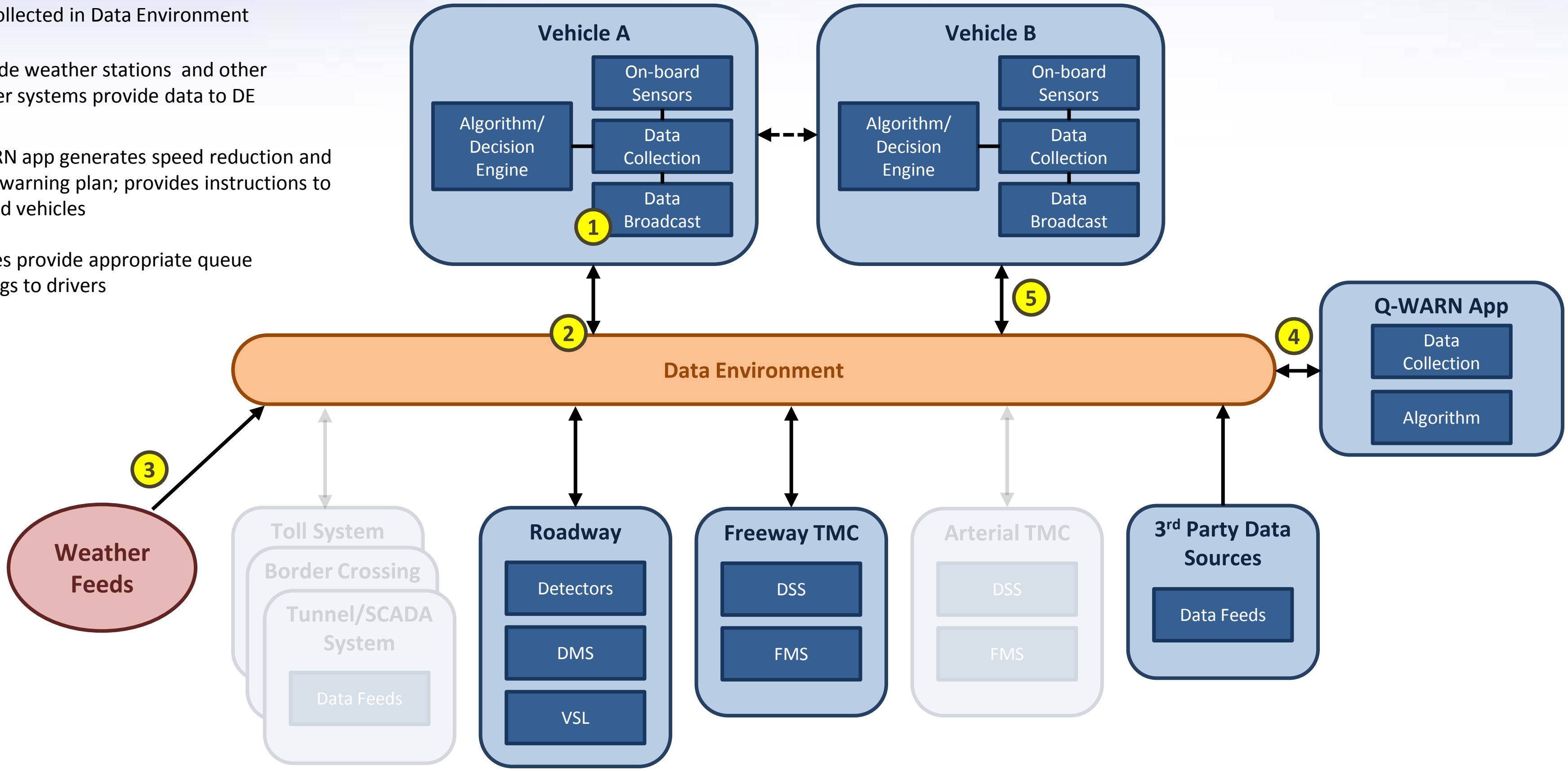
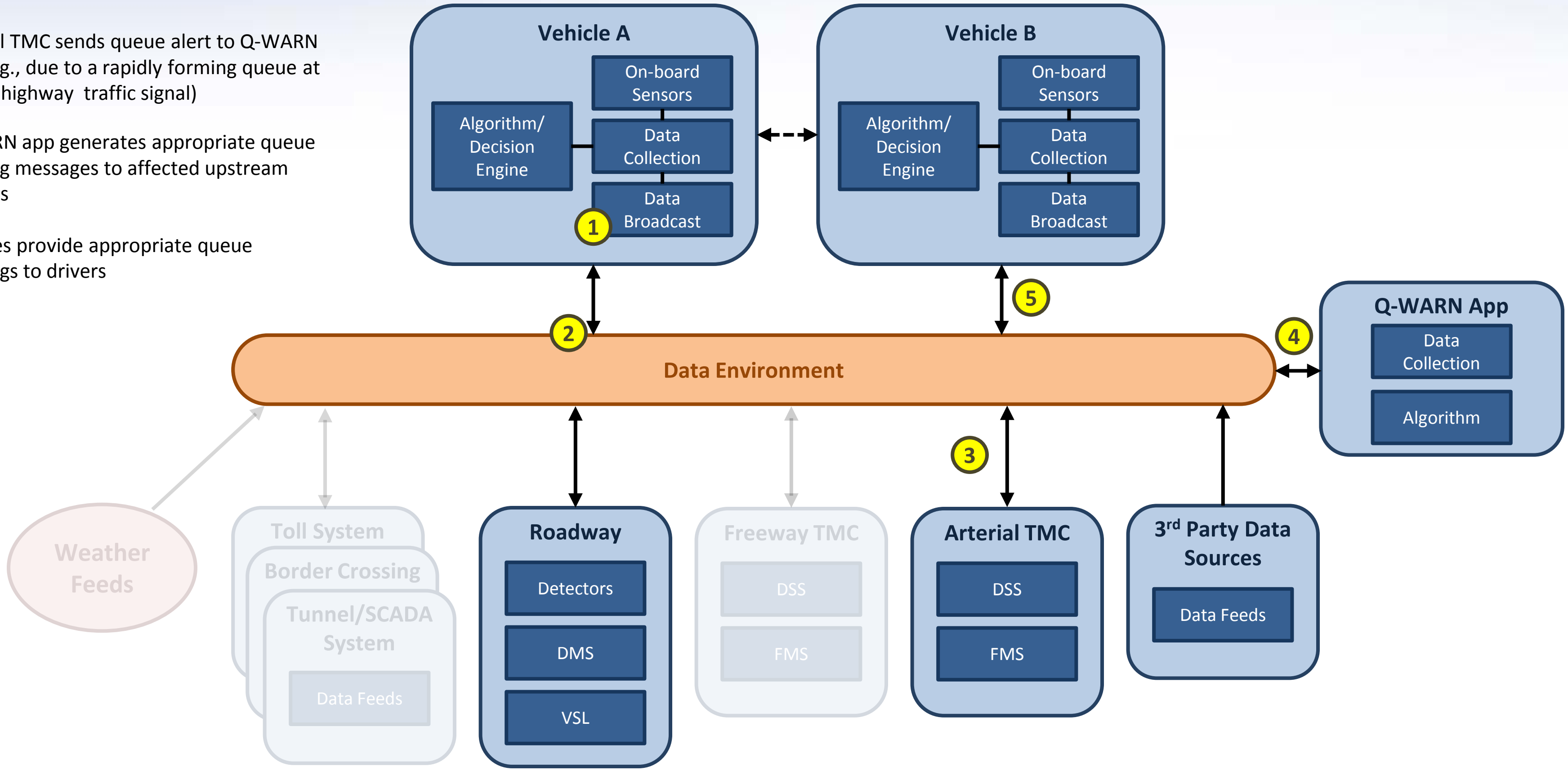
Q-WARN Scenario 3: Weather Event-Induced Queue

1. Vehicle broadcasts status information (speed, heading, location, etc.) and weather-related status information
2. Data collected in Data Environment
3. Roadside weather stations and other weather systems provide data to DE
4. Q-WARN app generates speed reduction and queue warning plan; provides instructions to affected vehicles
5. Vehicles provide appropriate queue warnings to drivers



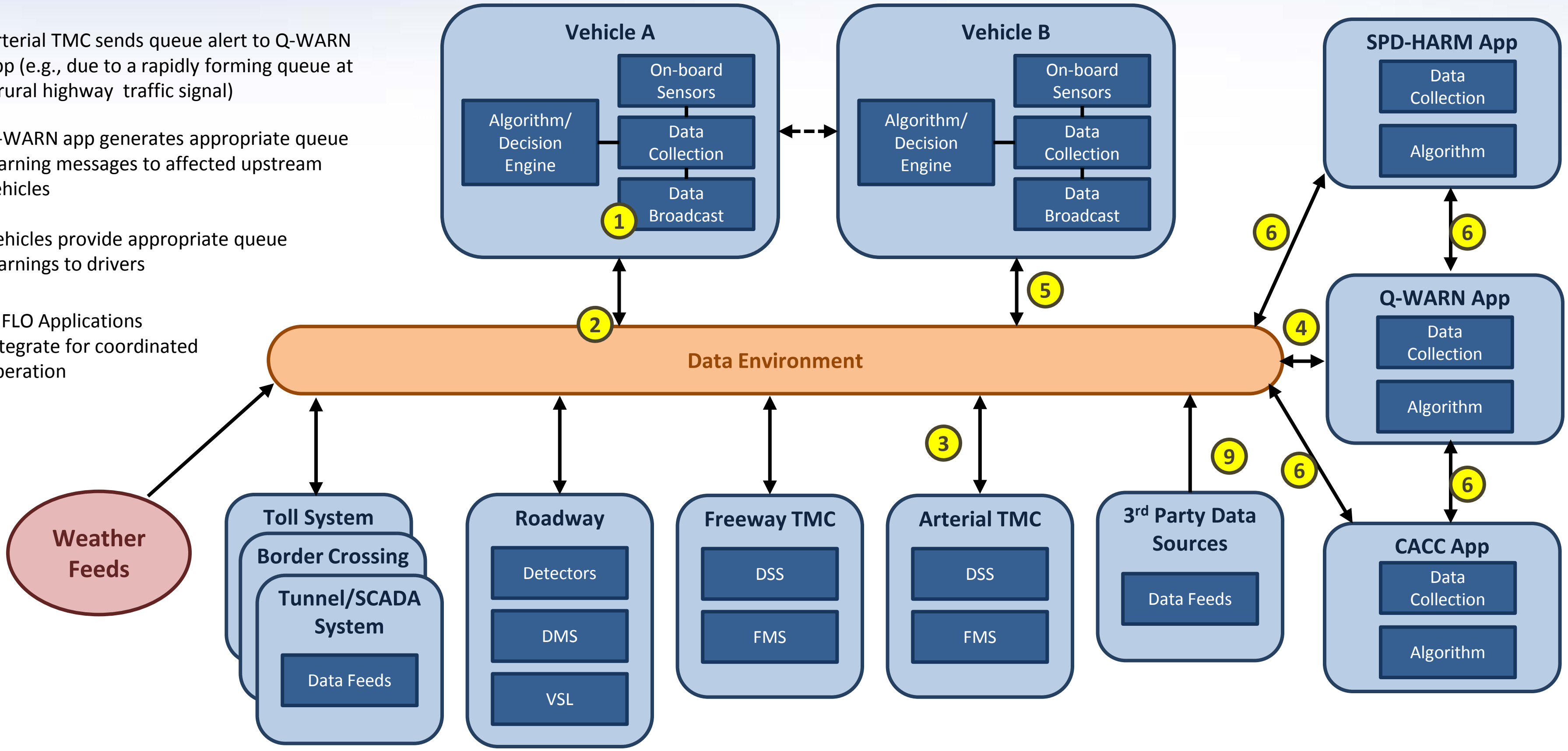
Q-WARN Scenario 4: Arterial Queuing

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Arterial TMC sends queue alert to Q-WARN app (e.g., due to a rapidly forming queue at a rural highway traffic signal)
4. Q-WARN app generates appropriate queue warning messages to affected upstream vehicles
5. Vehicles provide appropriate queue warnings to drivers



Q-WARN Scenario 5: INFLO Combined

1. Vehicle broadcasts status information (speed, heading, location, etc.)
2. Data collected in Data Environment
3. Arterial TMC sends queue alert to Q-WARN app (e.g., due to a rapidly forming queue at a rural highway traffic signal)
4. Q-WARN app generates appropriate queue warning messages to affected upstream vehicles
5. Vehicles provide appropriate queue warnings to drivers
6. INFLO Applications integrate for coordinated operation



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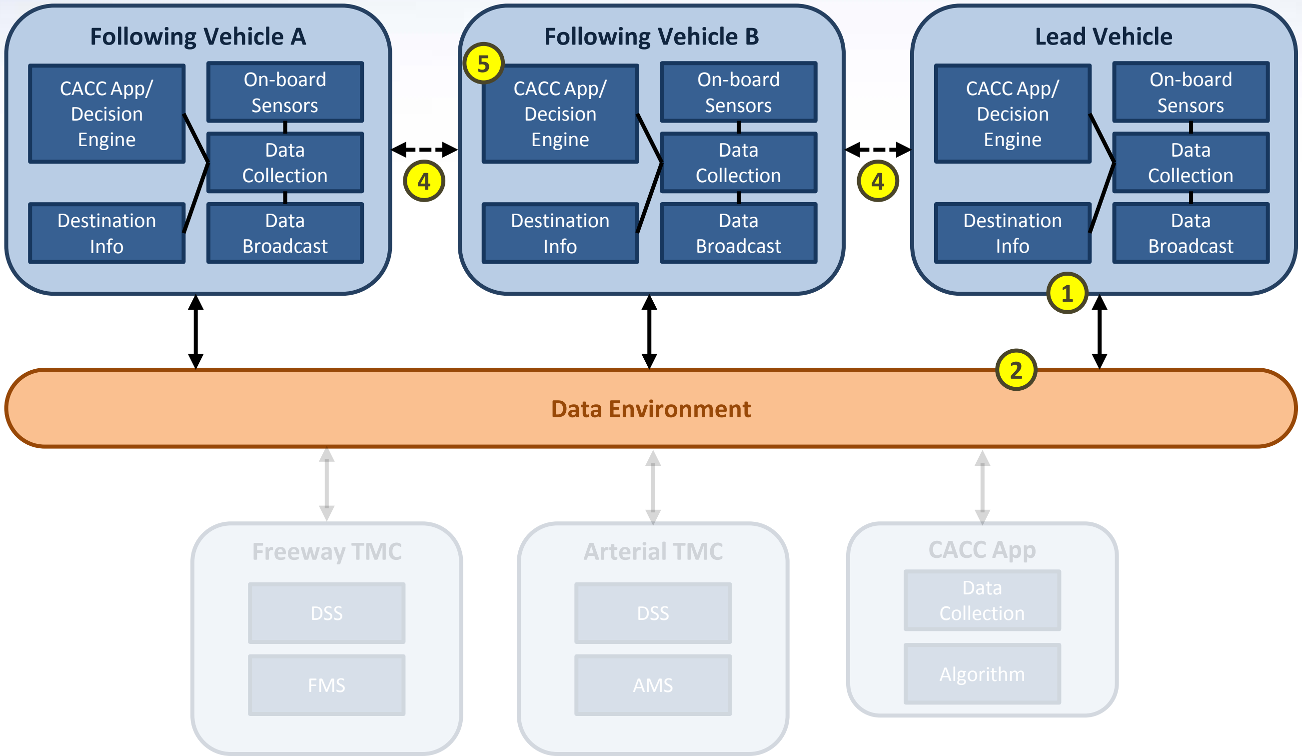
CACC Scenario 1: V2V Cooperative Platooning

1. Lead Vehicle broadcasts status information (speed, heading, location, etc.) and (optionally) destination information
2. Data collected in Data Environment
3. Vehicle B's CACC application determines that it can join the platoon
4. CACC applications on Lead Vehicle and Following Vehicle A coordinate Vehicle B's entry into platoon
5. Following Vehicles ' CACC applications coordinate speed and headway adjustments with Lead Vehicle; throttle, brakes, and (optionally) steering for Vehicle B is now semi-autonomous



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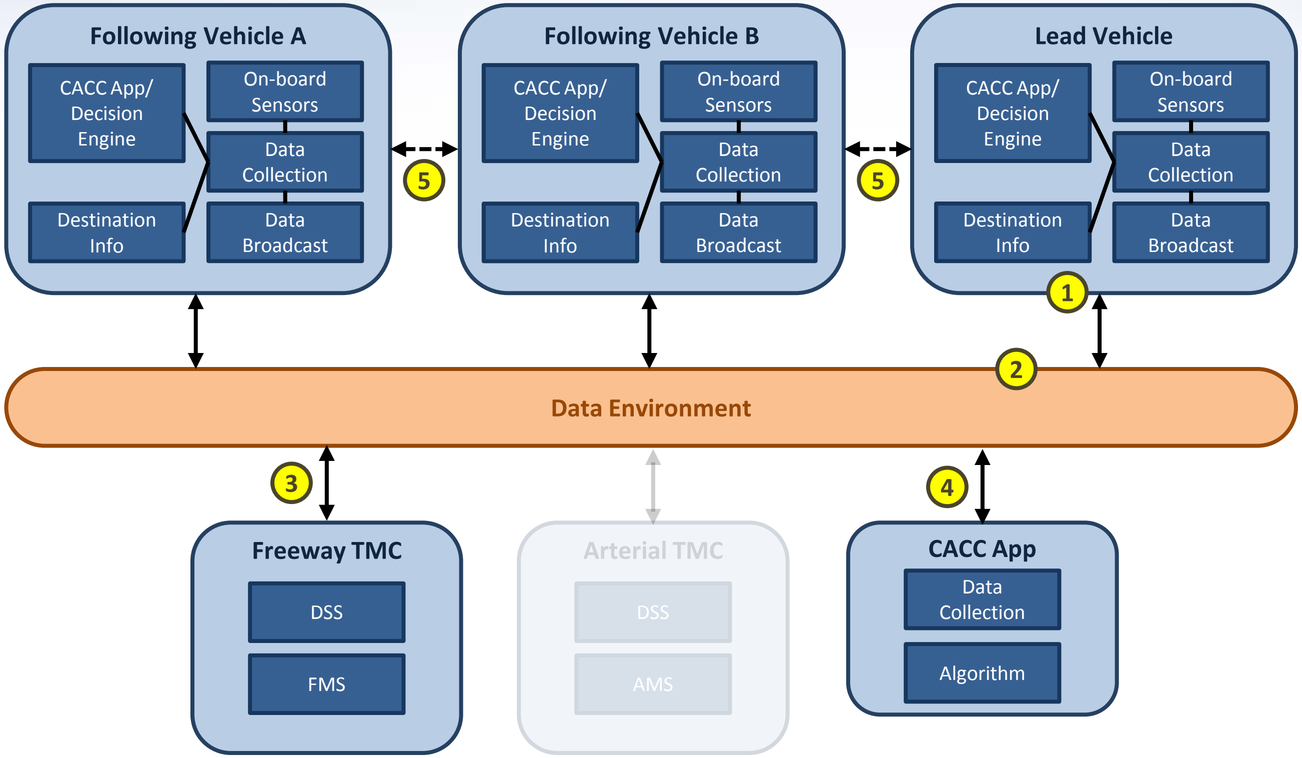
CACC Scenario 2: V2I Cooperative Platooning – Freeway

1. Vehicles broadcast status information (speed, heading, location, etc.) and (optionally) destination information
2. Data collected in Data Environment
3. Freeway TMC assigns platoons
4. CACC applications provides platoon assignments to vehicles
5. Vehicles ' CACC applications coordinate speed and headway adjustments with Lead Vehicle; throttle, brakes, and (optionally) steering for following vehicles is now semi-autonomous



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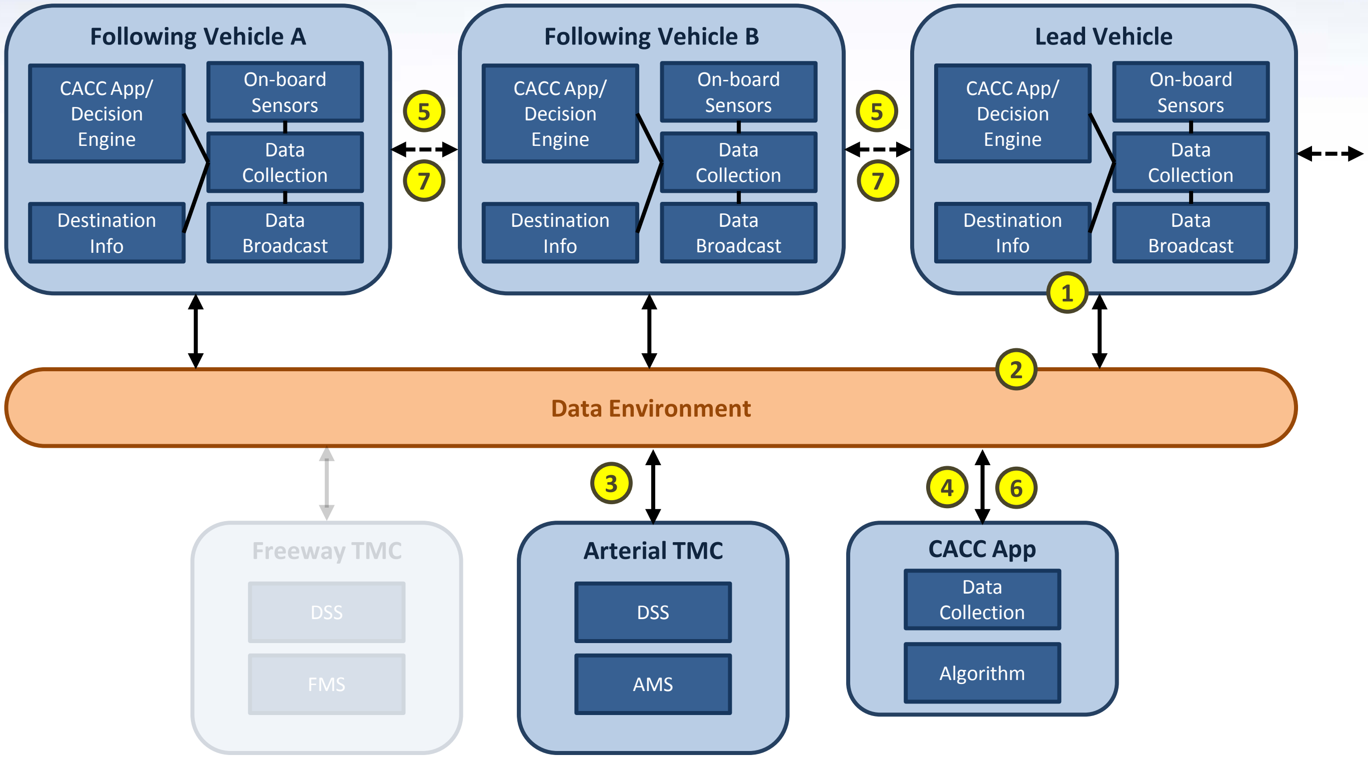
CACC Scenario 3: V2I Cooperative Platooning – Arterial

1. Vehicles stopped at a red light and broadcast status information (heading, location, etc.) and (optionally) destination information
2. Data collected in Data Environment
3. Arterial TMC identifies queue of vehicles as a potential platoon
4. CACC application provides platoon assignments to vehicles
5. Throttle, brakes, and (optionally) steering for vehicles is now semi-autonomous; when signal turns green, all vehicles accelerate simultaneously; on-board CACC applications coordinate speed and headway adjustments
6. As platoon advances through intersection it approaches another platoon ahead; CACC application instructs lead vehicle to join the rear of the platoon ahead
7. The two platoons merge and form a single platoon; on-board CACC applications coordinate speed and headway adjustments



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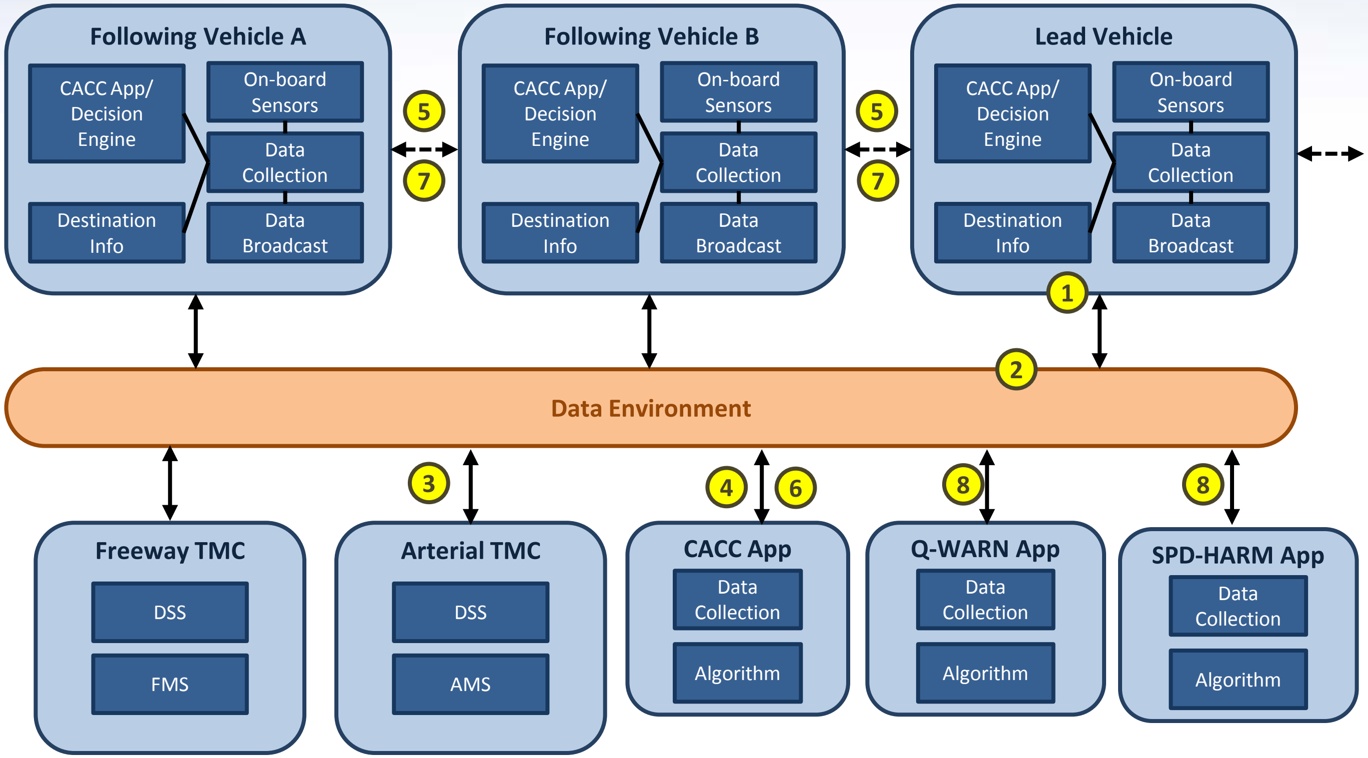
CACC Scenario 4: INFLO COMBINED

1. Vehicles stopped at a red light and broadcast status information (heading, location, etc.) and (optionally) destination information
2. Data collected in Data Environment
3. Arterial TMC identifies queue of vehicles as a potential platoon
4. CACC application provides platoon assignments to vehicles
5. Throttle, brakes, and (optionally) steering for vehicles is now semi-autonomous; when signal turns green, all vehicles accelerate simultaneously; on-board CACC applications coordinate speed and headway adjustments
6. As platoon advances through intersection it approaches another platoon ahead; CACC application instructs lead vehicle to join the rear of the platoon ahead
7. The two platoons merge and form a single platoon; on-board CACC applications coordinate speed and headway adjustments
8. INFLO Applications integrate for coordinated operation



Concurrent Breakouts

(Discuss User Needs for

SPD-HARM, Q-WARN and CACC)

3:15 p.m. – 4:15 p.m.

What are User Needs?

- Formally documented customer requirements. These inputs from you would be used as a starting basis for designing the INFLO DMA
- Mapped to the System Requirements
- We will be working with the DRAFT User Needs during this meeting in hopes of confirming them.

SPD-HARM User Needs (1)

	User Type	User Need	Description
1	Vehicle operator	Need the vehicle to be connected wirelessly to the SPD-HARM system	Vehicles should be wirelessly connected using Connected Vehicle or other conventional wireless technologies
2	Vehicle operator	Need to obtain specific traffic information from the vehicle or in-vehicle wireless devices	Information such as traffic flow, speed, acceleration/deceleration, weather, incidents or other information impacting traffic conditions should be pulled from the vehicle.
3	Vehicle operator	Need information on recommended or required speeds and lanes of travel should be provided to drivers	In order to enable speed harmonization, recommend maximum speeds as well as recommended lanes of travel will be provided to drivers within the vehicles.
4	Vehicles	Need to exchange traffic flow and traffic condition information from other vehicles	To enable true speed harmonization, communication with other nearby vehicles on the roadway will be required.
5	Roadway System	Need to obtain information from traditional roadway sensor systems, in near real time, to assess roadway conditions	To aid in speed harmonization, the SPD-HARM system should obtain traffic flow and speed information from existing sensors (Vehicle Detection Sensors) and other probe system sensors, if available

SPD-HARM User Needs (2)

	User Type	User Need	Description
6	Roadway System	Need to obtain information from traditional roadway weather sensor systems, in near real time, to assess roadway weather conditions	Need to obtain information, if available, from weather systems or weather sensors system to determine how and when speed harmonization should occur related to weather conditions
7	Roadway System	Need to disseminate speed harmonization information to other information dissemination systems on the roadway	To enable near-term gains, there may be a benefit in taking speed harmonization information obtained from the INFLO DMA and dissemination speed recommendations using traditional infrastructure, e.g. utilizing existing VSL or DMS signs.
8	Roadway System	Need to obtain information from ramp metering systems	To enable speed harmonization that is coordinated with ramp metering systems, there is a need to obtain real-time information from ramp metering systems or controllers
9	Roadway System	Need to obtain traffic information from arterial traffic signal systems	To facilitate speed harmonization on arterials, there is benefit in obtaining real-time data from traffic signals systems related to vehicle detection, signal time plans and signal coordination

SPD-HARM User Needs (3)

	User Type	User Need	Description
10	SPD-HARM Application/System	Need to develop a SPD-HARM algorithm and application.	Need to develop an application which collects data needed for speed harmonization, computes speed harmonization levels and recommendations based on an algorithm and disseminates this information to vehicles
11	SPD-HARM Application/System	Need to develop a SPD-HARM performance measurement system	There is a need to measure the performance of the system and algorithms both to understand performance, but to be able to tweak algorithms as required.
12	Other DMAs	The SPD-HARM system/application needs to be able to be interfaced with other DMA applications.	There are other applications, including Q-WARN and CACC, among others, that would benefit from direct coordination with the SPD-HARM Application.
13	DCM Environments	Needs to be able to be interfaced with the DCM Environments	The SPD-HARM system/application needs to be able to be interfaced with the Freeway and Arterial DCM Environments

SPD-HARM User Needs (4)

	User Type	User Need	Description
14	General	Need for standards related to the exchange of information with the DCM environments and other DMA applications	ITS Standards do not necessarily exist to support all the needs of this application and the associated DCM environments

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Q-WARN
User Needs

Q-WARN User Needs (1)

	User Type	User Need	Description
1	Vehicle operator	Need the vehicle to be connected wirelessly to the Q-WARN system/Application	Vehicles should be wirelessly connected using Connected Vehicle or other conventional wireless technologies
2	Vehicle operator	Need to obtain specific traffic information from the vehicle or in-vehicle wireless devices	Information such as traffic flow, speed, sudden deceleration, weather, incidents or other information impacting traffic conditions should be pulled from the vehicle.
3	Vehicle operator	Need information on impending traffic queue should be provided to drivers/vehicles	In order to enable queue warning, recommend queue warning information such as “BACKUP AHEAD, BE PREPARED TO STOP, 1/4/MILE”.
4	Vehicles	Need to exchange traffic flow, traffic condition and queue backup information from other vehicles	To enable real-time queue warning, communication with other nearby vehicles on the roadway will be required to assess queue lengths in real time
5	Roadway System	Need to obtain information from traditional roadway sensor systems, in near real time, to assess roadway conditions and queue lengths	To aid in Q-WARN, the system/application should obtain traffic flow and speed information from existing sensors (Vehicle Detection Sensors) and other probe system sensors, if available

Q-WARN User Needs (2)

	User Type	User Need	Description
6	Roadway System	Need to obtain roadway weather information to understand queuing conditions approaching weather event areas	Need to obtain information, if available, from weather systems or weather sensors system to identify queue areas associated with weather events, e.g. fog warnings, ice warnings, etc.
7	Roadway System	Need to disseminate queue warning information to other information dissemination systems on the roadway	To enable near-term gains, there may be a benefit in taking queue warning information obtained from the Q-WARN DMA and dissemination Q-WARN alerts utilizing existing DMS signs.
8	Roadway System	Need to obtain information from fixed queue generation points	To enable an effective queue warning system, it would be beneficial to obtain information from existing fixed queue generation points (e.g. border crossings, mainline metering, toll payment sites, etc.) especially those with queue length detection systems.
9	Roadway System	Need to obtain traffic information from arterial traffic signal systems	To facilitate queue warning on arterials, especially higher speed rural highways, there is benefit in obtaining real-time data from traffic signals systems to assist with impending queues and stop points.

Q-WARN User Needs (3)

	User Type	User Need	Description
10	Q-WARN Application/System	Need to develop a Q-WARN algorithm and application.	Need to develop an application which collects data needed for queue warning, computes queue lengths, recommends queue warning messages based on an algorithm and disseminates this information to vehicles
11	Q-WARN Application/System	Need to develop a Q-WARN performance measurement system	There is a need to measure the performance of the system and algorithms both to understand performance, but to be able to tweak algorithms as required.
12	Other DMAs	The Q-WARN system/application needs to be able to be interfaced with other DMA applications.	There are other applications, including SPD-HARM and CACC, among others, that would benefit from direct coordination with the Q-WARN Application.
13	DCM Environments	Needs to be able to be interfaced with the DCM Environments	The Q-WARN system/application needs to be able to be interfaced with the Freeway and Arterial DCM Environments

Q-WARN User Needs (4)

	User Type	User Need	Description
14	General	Need for standards related to the exchange of information with the DCM environments and other DMA applications	ITS Standards do not necessarily exist to support all the needs of this application and the associated DCM environments

CACC
User Needs

CACC User Needs (1)

	User Type	User Need	Description
1	Vehicle/Vehicle Operator	Need the vehicle to be connected wirelessly to other vehicles to enable the Q-WARN Application	Vehicles should be wirelessly connected using Connected Vehicle or other conventional wireless technologies
2	Vehicle/Vehicle Operator	Need to obtain specific vehicle information in real time from the vehicle or in-vehicle wireless devices	Information such as vehicle speed, acceleration, deceleration, braking, braking speed, fault warnings and other parameters associated with CACC should be obtained from the vehicles
3	Vehicle/Vehicle Operator	Need information on impending downstream traffic conditions that can be utilized by the CACC application	Sudden slowing conditions or other factors can be obtained from other vehicles or other sensors systems to help alert in activate the CACC application
4	Vehicles	Need to provide alerts, alarms and controls from vehicle to vehicle so appropriate CACC safety adjustments can be made	To enable real-time CACC, communication with other nearby vehicles on the roadway will be required to disseminate information in the form of alerts, alarms, controls to reduce vehicle gaps, perform braking alerts, reduce shockwaves and shockwave speeds, improve reaction times, etc.

CACC User Needs (2)

	User Type	User Need	Description
5	CACC Application/System	Need to develop a CACC algorithms and application.	Need to develop an application which collects data needed for CACC and performs the necessary calculations for latitudinal and longitudinal controls, gap reduction, shockwave speed reduction, improved action times and system alerting.
6	CACC Application/System	Need to develop a CACC performance measurement system	There is a need to measure the performance of the system and algorithms both to understand performance, but to be able to tweak algorithms as required.
7	Other DMAs	The CACC system/application needs to be able to be interfaced with other DMA applications.	There are other applications, including SPD-HARM and CACC, among others, that would benefit from direct coordination with the Q-WARN Application.
8	DCM Environments	Needs to be able to be interfaced with the DCM Environments.	The CACC system/application needs to be able to be interfaced with the Freeway and Arterial DCM Environments

CACC User Needs (3)

	User Type	User Need	Description
9	General	Need for standards related to the exchange of information with the DCM environments and other DMA applications	ITS Standards do not necessarily exist to support all the needs of this application and the associated DCM environments

Agenda (cont.)

1:30 p.m. – 1:45 p.m.	Applications Overview and Breakout Group Discussion Format
1:30 p.m. – 3:00 p.m.	Concurrent Breakouts (Discuss Application Scenarios for SPD-HARM, Q-WARN and CACC)
3:00 p.m. – 3:15 p.m.	**BREAK**
3:15 p.m. – 4:15 p.m.	Concurrent Breakouts (Discuss User Needs for SPD-HARM, Q-WARN and CACC)
4:15 p.m. – 4:45 p.m.	**Full Group Debriefs of each Application Breakout**
4:45 p.m. – 5:00 p.m.	Recap of Meeting, Next Steps and Conclusion

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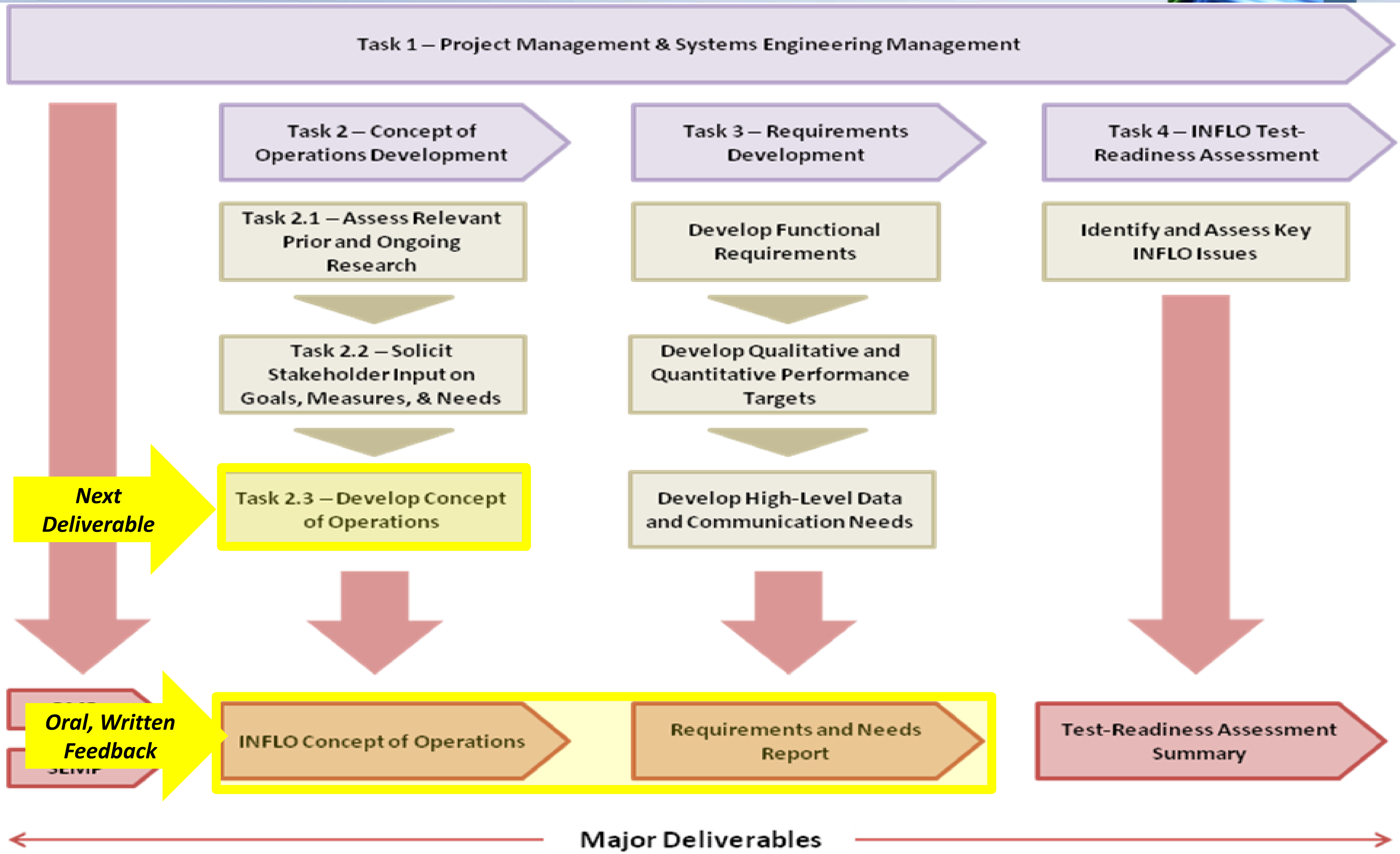
Project Tasks and Stakeholder Involvement



Next Steps

- Task 2:
  - Final Assessment Report: 2/10/12
  - Draft Stakeholder Input Report 2/16/12
  - Draft Concept of Operations 3/28/12
  - ConOps Walkthrough 5/11/12
  - Final Concept of Operations 5/14/12
- Task 3
  - Draft INFLO Requirements 6/22/12
  - Requirements Walkthrough 8/7/12
  - Final INFLO Requirements 8/21/12
- Task 4
  - Draft Test Readiness Assessment: 9/18/12

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