UNITED STATES
DEPARTMENT OF TRANSPORTATION

COLLABORATIVE CONNECTED VEHICLE RESEARCH UPDATE

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Collaborative Research Overview

- Collaborative effort between Crash Avoidance Metrics Partnership Vehicle Safety Communications 3 (CAMP VSC3) Consortium US DOT
- Seven active projects

APPLICATION DEVELOPMENT PROJECTS (2)

- Goals:
  - Characterize system performance of mature prototype applications (OEM proprietary) that may combine V2V communications with other on-board safety sensors
  - Use the characterization in the Safety Benefits analysis
- Forward Collision Avoidance Applications
  - Five OEMs participating
  - Testing completed: achieved good results from initial test session
- Intersection Collision Avoidance Applications
  - Three OEMs participating
  - Testing is scheduled to begin in May 2013
- No final project report

Light Vehicle Driver Acceptance Clinics and System Performance Test Project

Objectives:

- Obtain feedback on connected vehicle technology and safety applications from a representative sample of drivers
- Assess the performance and reliability of 5.9 GHz DSRC communications and GPS in diverse geographic locations and environmental conditions…and
- Promote V2V-based safety technology and potential safety benefits

User Acceptance – Driver Clinics

- 6 locations across the U.S. - began in August 2011
- Over100 drivers per location
- Crash Warning Applications
  - Forward Crash Warning
  - Emergency Brake Light
  - Blind Spot Warning
  - Lane Change Warning
  - Intersection Assist
  - Do Not Pass Warning

Driver Acceptance Clinics Conclusions

- About 700 participants experienced V2V safety across 10 scenarios (over 7,000 warnings issued) without a single adverse event.
- More than 45,000 individual responses were solicited
  - 100% of the participants were exposed to FCW, BSW, LCW, EEBL, and IMA
  - 37% experienced the DNPW, and
  - 25% experienced LTA.
- Analysis indicates that drivers are accepting of the V2V technology.
  - Drivers had very high acceptance and indeed a desire to have the technology deployed
  - 91% of the drivers felt the V2V technology was either “absolutely necessary” or “nice to have” after training, but prior to exposure
  - Post-exposure desirability increased to 93%
- Final report is under USDOT review

System Performance Testing Conclusions

- Current production automotive navigational-grade (low cost) GPS receivers can perform very well for V2V safety applications
- Good relative positioning performance
  - Lane-level in most environments
  - Road-level achievable in all environments
  - Deep urban most challenging
- *Applications can be designed to have graceful degradation* (e.g. road level to lane level) during GPS degradation periods based on feedback from GPS receiver (via the error ellipse, residual errors, etc).
- Wireless communications are reliable for V2V safety communications in all environments.
- Application performance shows improvements over the lower positioning layer, made possible through the use of path history & path prediction. Further tuning, filtering, and heuristics can improve the V2V safety applications.
- Final report is under USDOT review

V2V Interoperability Phase 1

- Project Goals
  - Address 5.9 GHz DSRC technical issues related to interoperability, scalability, security, and data integrity / reliability
  - Provide necessary inputs into the relevant standards development and related efforts, as required, in order to ensure a deployable standards-based system
- Project ended in Aug 2012
- Final Report is under USDOT review

V2V Interoperability Phase 1

- Major Accomplishments
  - Achieved device level Vehicle-to-Vehicle (V2V) safety communications and security interoperability between OBEs from different manufacturers
  - Designed, prototyped and demonstrated a V2V security system. Demonstrated that V2V OBEs from multiple suppliers were able to *request* and *receive* security credentials received from a server remotely located in the CAMP VSC3 lab *and verify* credentials from other devices for the following channel configurations:
    - Channel 174 (adjacent channel to the other 196 units)
    - Channel 172 (same as 196 unite)
    - Cellular 3G
  - Developed the SP BSM Minimum Performance Requirements
  - Participated in US-EU standards harmonization

SCALABILITY TESTING

…and in reality

V2V Interoperability Phase 1

- Channel Scalability Accomplishments
  - Implemented two transmission control protocols for scalable V2V safety communications
    - Algorithm X – Adaptive transmission rate and power
    - Algorithm Y – Adaptive transmission rate
  - Defined metrics for analyzing protocol performance
  - Validated protocol effectiveness in real-world driving scenarios involving 50 to 200 vehicles
  - Developed a Proof-of-Concept NS-2 simulator for IEEE 802.11p DSRC which:
    - Accepts real mobility traces obtained from the field testing
    - Enabled evaluation of the simulation results with respect to the field testing results

V2V Interoperability Phase 1

- Scalability Research Conclusions
  - With congestion from 200 vehicles, V2V safety application scenario warnings were provided within the nominal warning range for all transmit protocols
  - Both algorithms show promising communication performance for up to at least 200 vehicles while reducing the channel utilization below 10Hz transmit levels
  - Due to the congestion level never reaching the point of saturation, a recommendation on a V2V safety communication congestion control approach could not be made

V2V Interoperability Phase 2 Scalability Efforts

- Goal: Finalize V2V safety communication technique(s) that will support large-scale deployment level of vehicles while preserving the performance of V2V safety applications
- Activities:
  - Calibration of communication simulation environments
  - Algorithm refinement and, if necessary, development of alternate approaches
  - Field testing
  - Incorporate recommendations into standards

V2V Interoperability Phase 2 Simulation Update

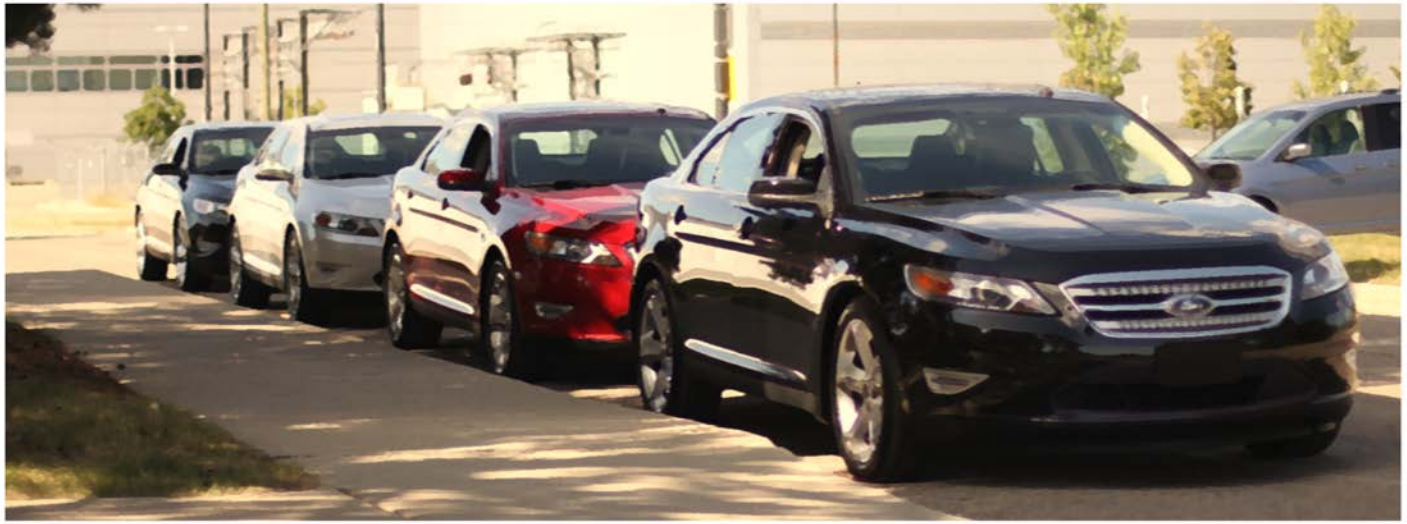
- Contracted two universities to work independently to calibrate simulation to real-world field test results
- Will move beyond field data and provide simulation results for full-deployment levels of vehicles
  - Algorithm refinements through simulation
  - Channel break-point determination
- Results will be verified through field tests

V2V Interoperability Phase 2 Field Testing

- Field testing will rely primarily on static On-Board Equipment (OBEs) mounted on carts
- Up to 400 OBEs will ultimately be used for testing
- Fewer moving vehicles will be used relative to Phase 1 testing
- Increased focus on safety application performance with channel congestion

V2V Model Deployment Project

- Build and maintain sixty-four integrated light vehicles for Safety Pilot Model Deployment
- Harvest data monthly for the independent evaluation of safety benefits
- Establish BSM minimum performance requirements based upon Safety Pilot data analysis

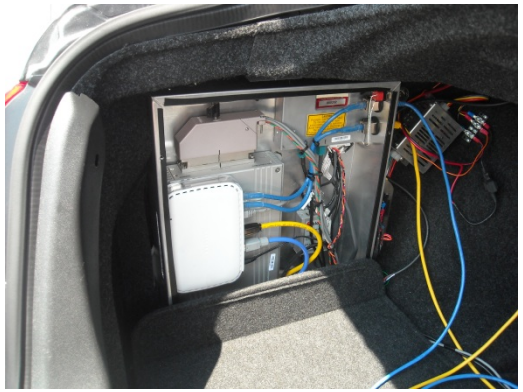


INTEGRATED VEHICLE BUILDS

V2V Key Components and Example Installations

Power, IGN sense, RS-232, GPS Serial Ethernet, 2xUSB1.1, GPIO (3 in, 1 out), Ground, 2xCAN – 38 pin automotive

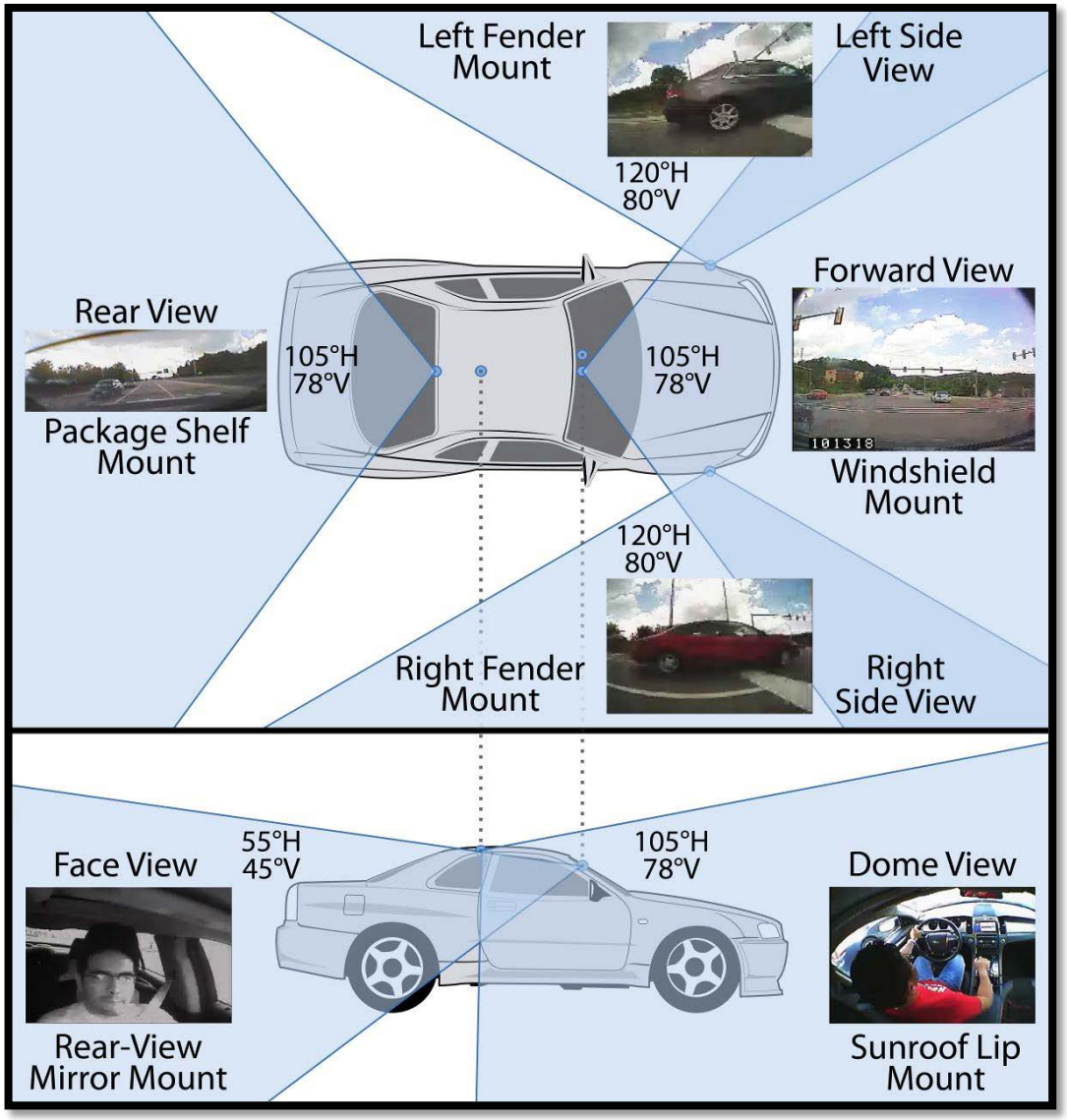
5.9 GHz DSRC (RX diversity) FAKRA Z – coaxial RF bulkhead

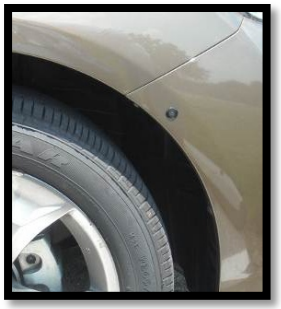


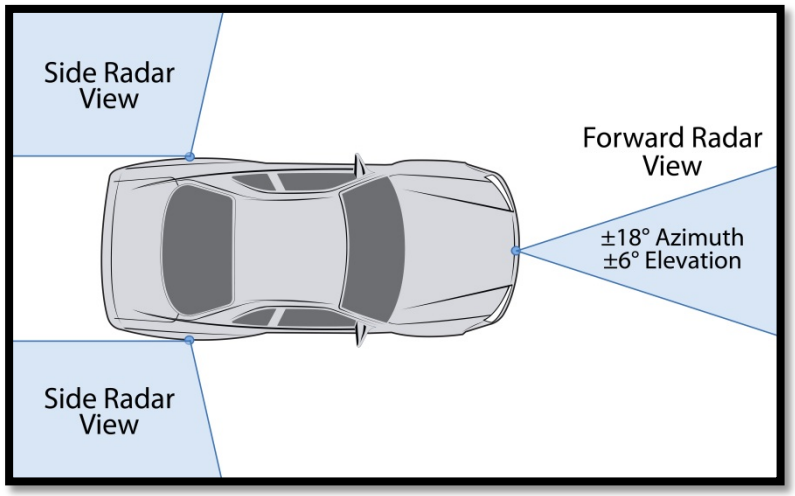
Security Framework Access Device (SFAD) Phase 2 of Model Deployment

- Sixteen SFAD equipped vehicles (2 per OEM)
  - Perform over-the-air security credential management
  - Eight communicate via DSRC
  - Eight communicate via 3G cellular
  - Automatically perform monthly updates of short term certificates
    - Initial batch loaded at initialization
    - subsequent batches automatically loaded over-the-air
    - Fallback mechanisms (down to Phase I configuration) are still in place
  - Introduced into Model Deployment March 2013
- Forty-eight non-SFAD equipped vehicles
  - Use short term certificates preloaded on USB drives

DAS Components Camera & Radar Views



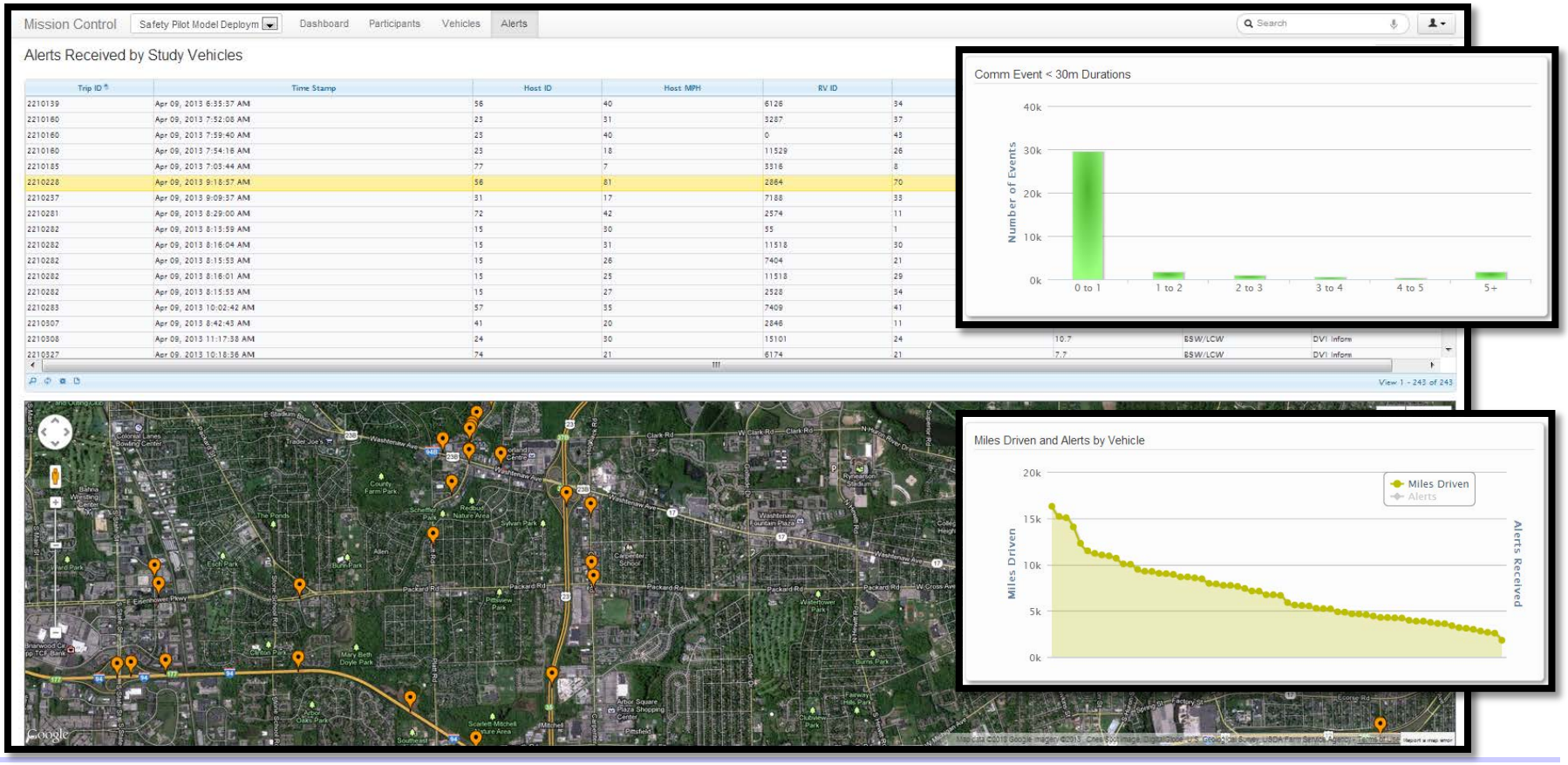




MAINTAINING THE FLEET

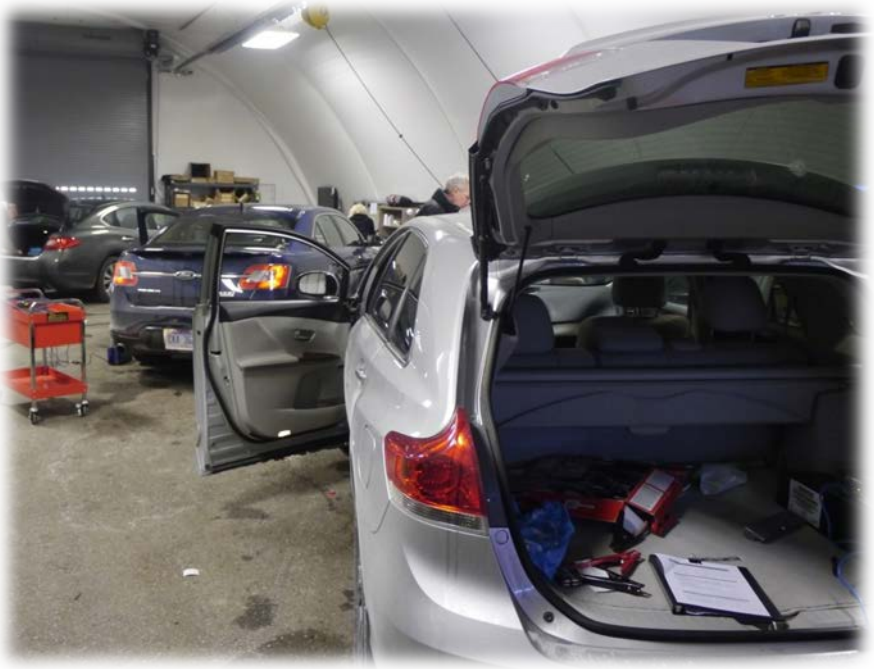
Remote Monitoring

- All vehicles are remotely monitored via cell link
  - Study parameters are tracked to ensure exposure is sufficient
  - Systems are scheduled for repair when anomalies detected



Data Harvesting and Fleet Status

- Harvest
  - Performed Monthly
  - Data is harvested via removable HD
  - Vehicle systems verified
- Status @~6 Months
  - Miles Driven: 446,919
  - Trips: 67,962
  - V2V Comms: 536,608
  - Comms < 30m: 34,445



Data Sharing – Volpe, UMTRI, & TFHRC

Volpe

- CAMP and VTTI providing a set of numerical and video data to Volpe
- Volpe serves as the Independent Evaluator
- Performs the analysis for the DOT

CAMP & VTTI

- Performing a series analyses on system performance

UMTRI (PCAP Files)

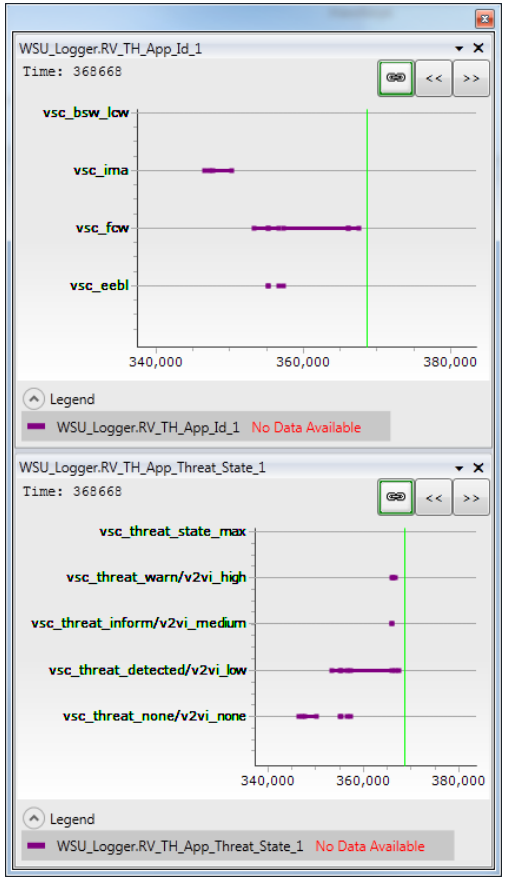
- CAMP and VTTI providing PCAP files
- UMTRI compiling V2V BSM database from PCAP

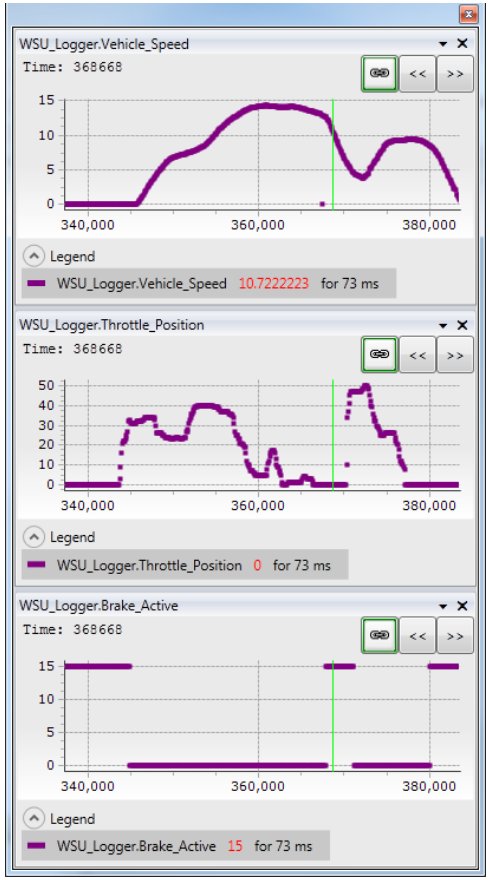
TFHRC

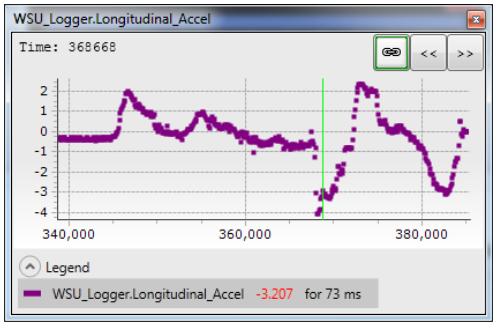
- CAMP and VTTI providing a subset of numerical data for the Real-time Data Capture Management Program.

Event Examples

FCW

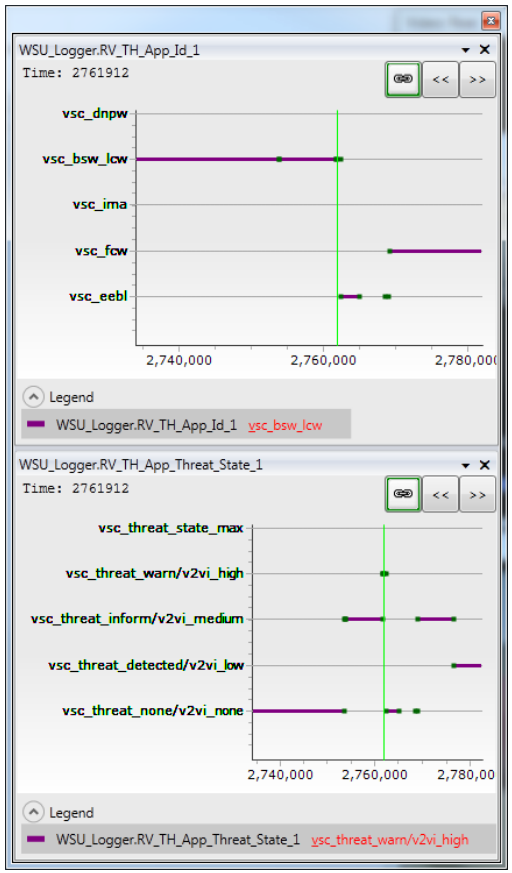


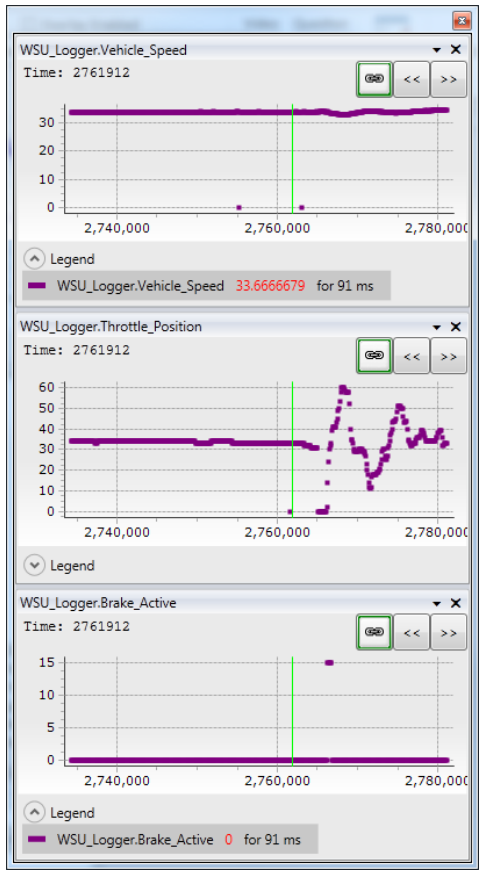




Event Examples

BSW

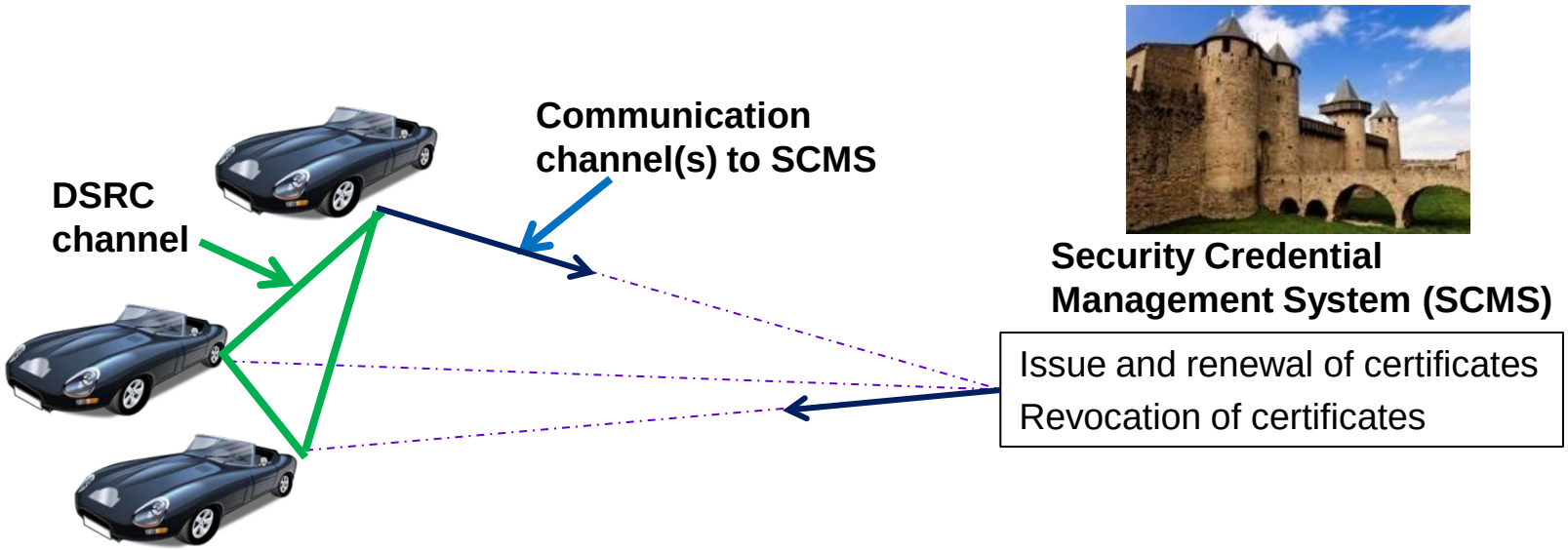




V2V Security
Why do we need it?

- The receiver of a message is not able to determine, without additional mechanisms, whether
  - a message originates from a trustworthy and legitimate device, and whether
  - the message was modified between the sender and the receiver.
- Public Key Infrastructure is necessary for a system that relies upon vehicles trusting messages ***broadcasted*** by other vehicles

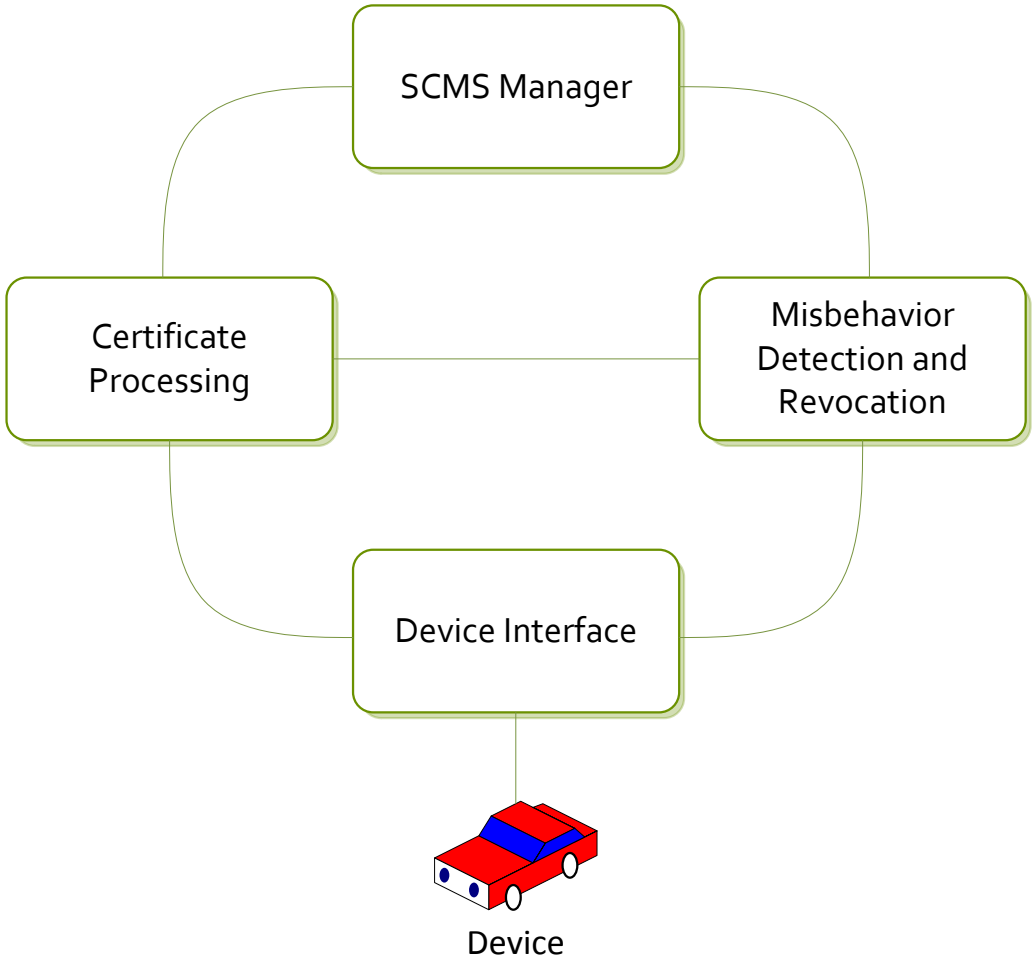
V2V Security Communications



Three types of communications

- Basic safety message broadcasts from vehicles
- Communication Channel from Vehicles to SCMS
  - Send misbehavior reports (messages flagged by local misbehavior detection)
- Communication Channel from SCMS to Vehicles
  - Issue New Certificates
  - Update Vehicles with Certificate Revocation List

High Level SCMS Technical Structure



Main Operations:

1. Device Initialization
2. Certificate Provisioning
3. Misbehavior Detection and Revocation

Communications Security Research Recent Accomplishments

- Defined a deployment model for connected vehicle security for a vehicle-to-vehicle warning system, including an initial deployment model, an end-state model and the transition between the two
- Identified potential design simplifications using risk assessment techniques
- Refined SCMS design for functions such as device initialization, certificate provisioning, and misbehavior detection and revocation
- Identified restriction for operating different SCMS components
- Documented the technical considerations for OEMs for potential involvement in the operation of SCMS components

Current Communications Security Research Study

Title: Design Optimization and Cost Analysis of Connected Vehicle Security System

Period of Performance: April 3, 2013 – January 3, 2014

Activities:

- Define baseline security model and baseline OBE requirements
- Develop security system cost model
- Perform cost analysis on baseline security model
- Analyze potential simplifications to the deployment model
- Analyze alternative device-SCMS connectivity approaches
- Identify technical approaches to linking enrollment certificates to batches of devices to aid defect investigations
- Provide design recommendations for V2V Security System

Communications Security Research Upcoming Research Activity

- Misbehavior Detection and Reporting
  - Consider both Local and Global Misbehavior Detection
  - Explore one or more detection schemes that could potentially be suitable for initial deployment
  - Consider communication protocol and/or data elements

Questions?

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