V2V RESEARCH
CRASH, PERFORMANCE, AND TESTS

ITS Workshop on Connected Vehicles:
Moving from Research Towards Implementation

September 25, 2012

V2V Safety Framework

Maturing the V2V Research	Model Deployment	Evaluation	Supporting Policy Elements	Moving Towards a Decision
Initial Crash Problems	Benefits Framework	Evaluation Plan	Implementation	Safety Benefits
Performance Measures	Driver Clinics	Data	Technical	Performance Requirements
Testing Procedures	Performance Testing	Conduct Evaluation	Legal	Test Procedures
Interoperability Requirements	Model Deployment	Run Simulations		Driver Acceptance
Initial Security Models	Experimental Design			
Driver Vehicle Interface Guidance				

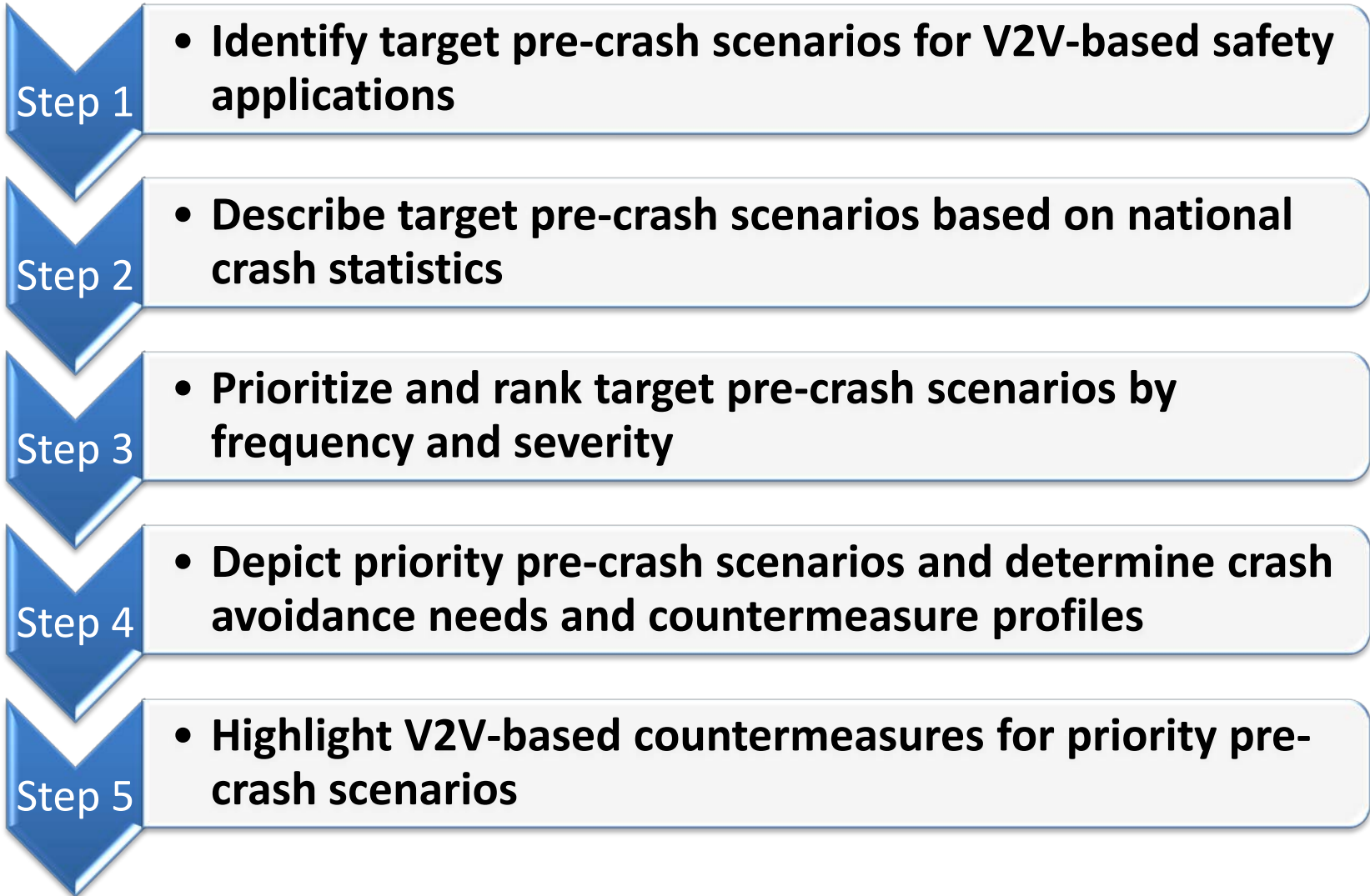Moving Towards an Operation Model → Data Collection → Data Evaluation & Analysis → Establishing an Operational Environment → Results
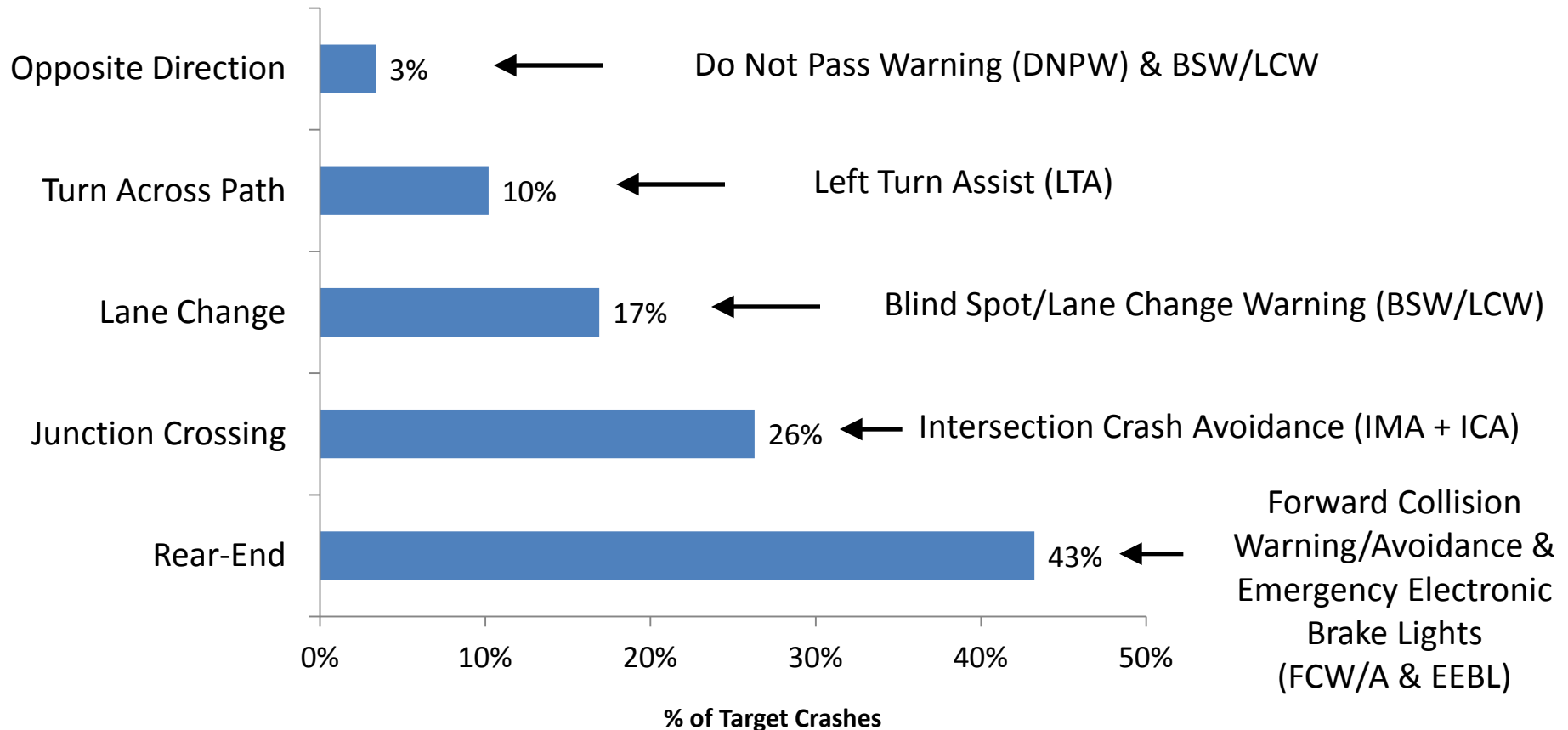
Pre-Crash Scenario Framework

Step 1 • **Identify target pre-crash scenarios for V2V-based safety applications**

Step 2 • **Describe target pre-crash scenarios based on national crash statistics**

Step 3 • **Prioritize and rank target pre-crash scenarios by frequency and severity**

Step 4 • **Depict priority pre-crash scenarios and determine crash avoidance needs and countermeasure profiles**

Step 5 • **Highlight V2V-based countermeasures for priority pre-crash scenarios**

Target V2V Crashes

37 Pre-Crash Scenarios
All Light-Vehicle (LV) Crashes **(5,726,000)**   **Unimpaired** LV Crashes **(5,355,000)**

22 V2V Pre-Crash Scenarios
4,336,000 LV Crashes
(**76%** of **All** LV Crashes, **81%** of **Unimpaired** LV Crashes)

15 V2I or Single Vehicle Pre-Crash Scenarios
24% of **All** LV Crashes
19% of **Unimpaired** LV Crashes
Not Used

17 Target V2V Scenarios
3,662,000 LV Crashes
(**64%** of **All**, 68% of **Unimpaired**)

5 Rear-End	2 Opposite Direction
3 Lane Change	3 Junction Crossing
2 LTAP/OD (all intersections)	
2 Traffic Control Device Violation	

5 V2V Pre-Crash Scenarios
12% of **All** LV Crashes
13% of **Unimpaired** LV Crashes)
Not Used

2 Control Loss
1 Backing
1 Parking
1 Other

10 Priority Scenarios
3,224,000 LV Crashes
(**56%** of **All**, **60%** of **Unimpaired**)

3 Rear-End	3 Lane Change
2 Opposite Direction	1 LTAP/OD
1 Junction Crossing	

W.G. Najm, J.D. Smith, and M. Yanagisawa, *Pre-Crash Scenario Typology for Crash Avoidance Research*. DOT HS 810 767, U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, DC, April 2007.

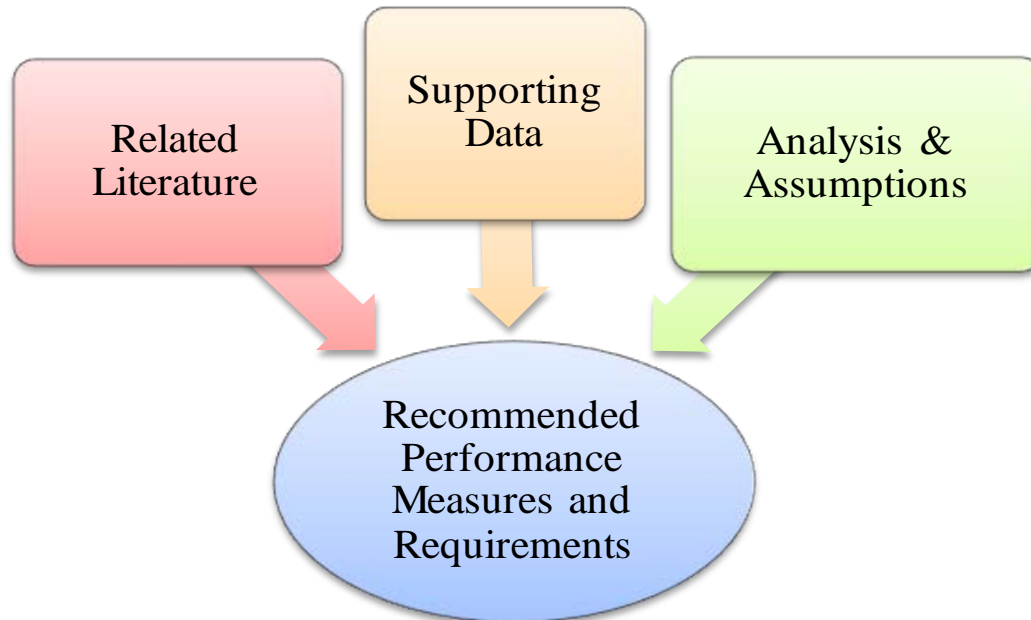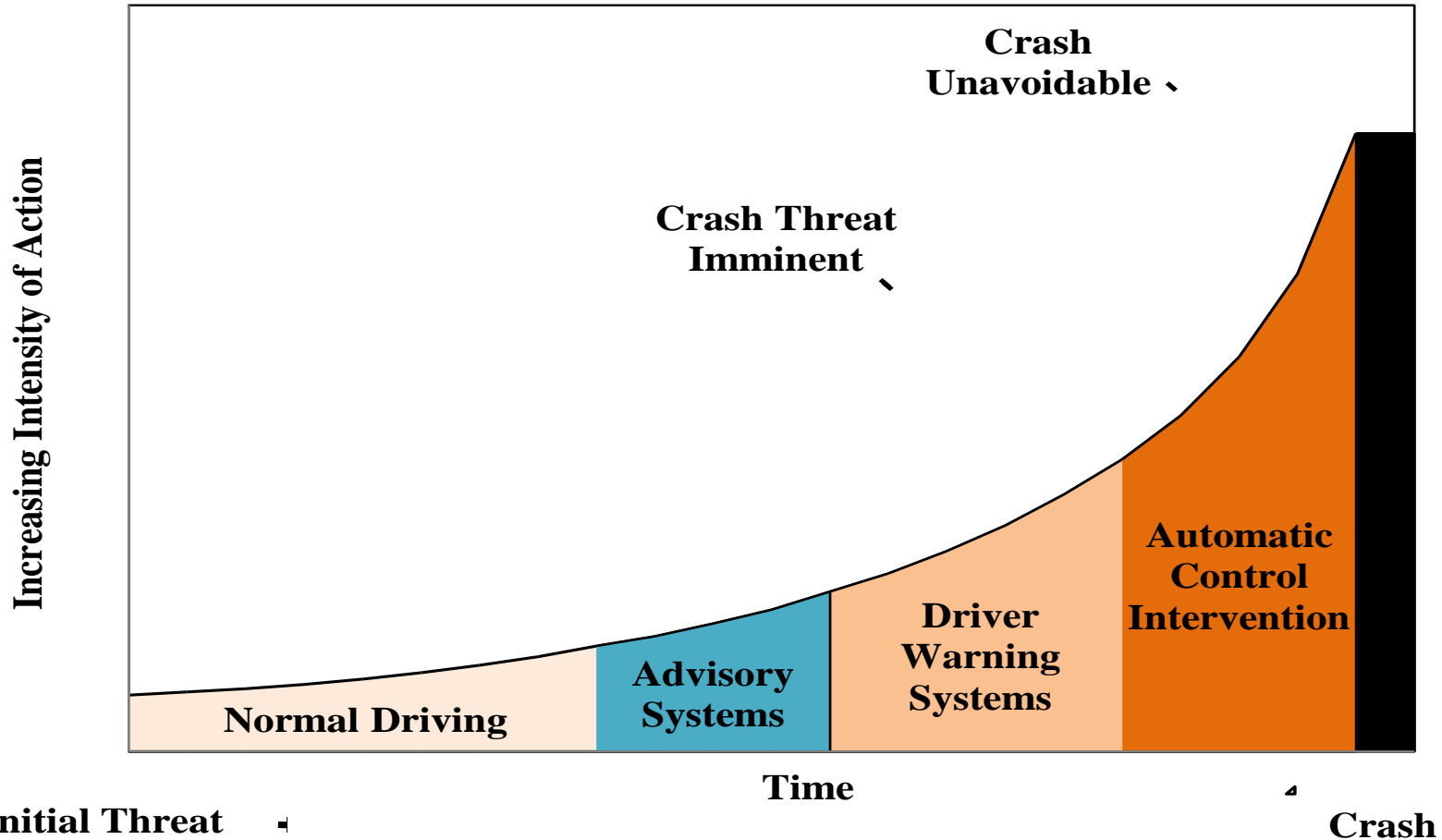# Target V2V Scenario Groups by Safety Application

Scenario Group	% of Target Crashes	Safety Application
Opposite Direction	3%	Do Not Pass Warning (DNPW) & BSW/LCW
Turn Across Path	10%	Left Turn Assist (LTA)
Lane Change	17%	Blind Spot/Lane Change Warning (BSW/LCW)
Junction Crossing	26%	Intersection Crash Avoidance (IMA + ICA)
Rear-End	43%	Forward Collision Warning/Avoidance & Emergency Electronic Brake Lights (FCW/A & EEBL)

% of Target Crashes

Preliminary Performance Measures

Crash Avoidance Groups

Rear-End	Lane Change	Opposite Direction	Junction Crossing	LTAP/OD

Methodology

Related Literature

Supporting Data

Analysis & Assumptions

Recommended Performance Measures and Requirements

Three Crash Avoidance Action Categories

Performance Metrics

Driver Reaction Time
Depends on:
- age
- gender
- physical & psychological state
- etc.

Braking Level
Depends on:
- speed
- range
- closing rate
- ttc
- etc.

Braking Level
Braking level known plus additional cosiderations:
- brake subsystem delay
- hydraulic pressure or deceleration build-up
- maximum level of braking
- brake characteristics
- etc.

REAR END

- **Purpose**
  - Forward Crash Warning (FCW) system detects vehicles in the path of the host vehicle, determines the likelihood of collision, and warns the driver of impending collisions.
  - Forward Crash Avoidance (FCA) system automatically applies the brakes in addition to the FCW function.
  - Comprises LVS, LVM, and LVD scenarios

- **Literature Study**
  - Crash Avoidance Metrics Partnership (CAMP)
  - International Standards Organization (ISO)
  - Integrated Vehicle-Based Safety System (IVBSS)
  - New Car Assessment Program (NCAP)

- **Crash Databases**
  - National Automotive Sampling System (GES)
  - Event Data Recorder (EDR)

- **Field Operational Test (FOT)**
  - IVBSS

REAR END – FCW and FCA Input Performance Measures Variables

Parameter	Source	
Instantaneous host vehicle speed	In-Vehicle and/or GPS	
Instantaneous host vehicle acceleration	In-Vehicle, GPS, or computed	
Predicted average acceleration (braking) by driver due to warning	FCW - Estimated by system	FCA - System Based
Driver reaction time to warning	FCW - Estimated by system	FCA - Zero
Total system delay including computation and attaining average acceleration (brake level)	System Based	
Instantaneous remote vehicle speed	In-Vehicle and/or GPS	
Instantaneous remote vehicle acceleration	In-Vehicle, GPS, or computed	
Median expected (braking – measured by FOT's) remote vehicle acceleration	Estimated by system designer	
Instantaneous range between host and remote vehicles	GPS	
Instantaneous range rate (relative speed) between host and remote vehicles	GPS	
Instantaneous relative speed rate (relative acceleration) between host and remote vehicles	GPS	

REAR END – FCW and FCA Output Performance Measures

- **Time-to-collision and Range for Advisory Warning**

- **Time-to-collision and Range for Imminent Warning**

- **Time-to-collision and Range for Automatic Braking**

Testing Procedures

Device Certification

- Interoperability
  - Ensures devices can communicate with other devices
  - Form, transmit, receive, and process BSM
  - Assess compliance with device specifications

Safety Application Performance (Objective Tests)

- Measure performance of crash avoidance applications
  - Does application operate as prototype design intent
    - Acceptable for Model Deployment (Warning)
  - Characterize performance for simulation
    - Warning and extended prototype to support benefit estimation
      - Forward Crash Avoidance and Intersection Crash Avoidance

Objective Test Procedures

- Procedure Requirements
  - Testing Approach
  - Countermeasure Modality Requirements
  - Objective Test Run Validity Criteria
  - Instrumentation, Equipment Installation, Calibration
  - Data Collection Requirements
  - Environmental, Ambient, and Standard Test Conditions
  - Suspension Criteria
  - Safety Protocols
  - Crash Imminent Test Scenarios
  - No-Action Test Scenarios

Connected Vehicles Testing

Rear End Forward Collision Avoidance

October 2012 – February 2013

Junction Crossing Intersection Collision Avoidance

March 2013 – July 2013
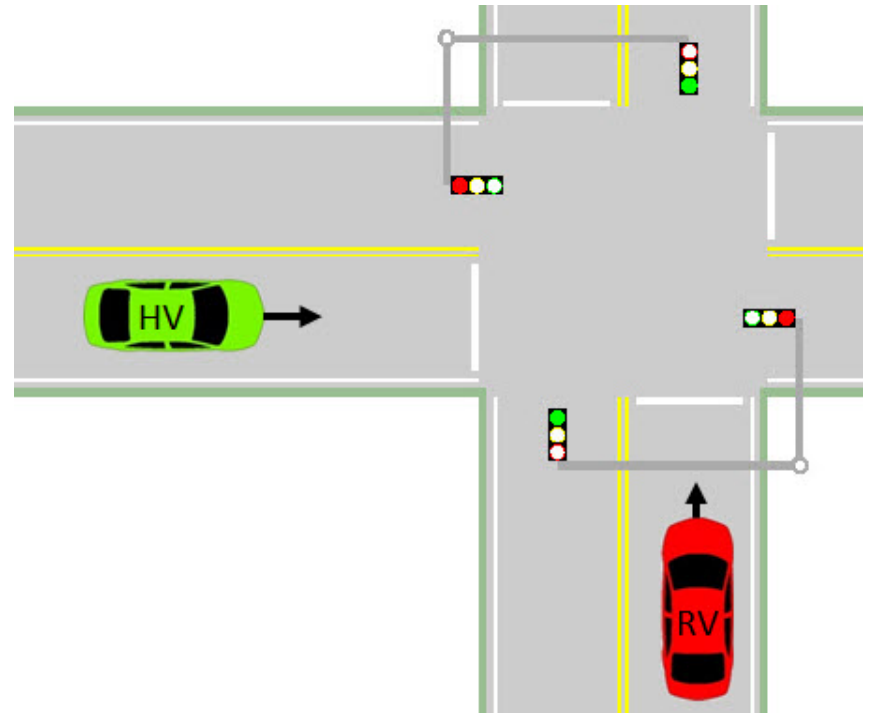
Safety Application Characterization Tests

Initial Conditions

Host vehicle is traveling at constant speed, V_H. Remote vehicle is traveling at the same constant speed, at specified range, $R_{Initial}$.
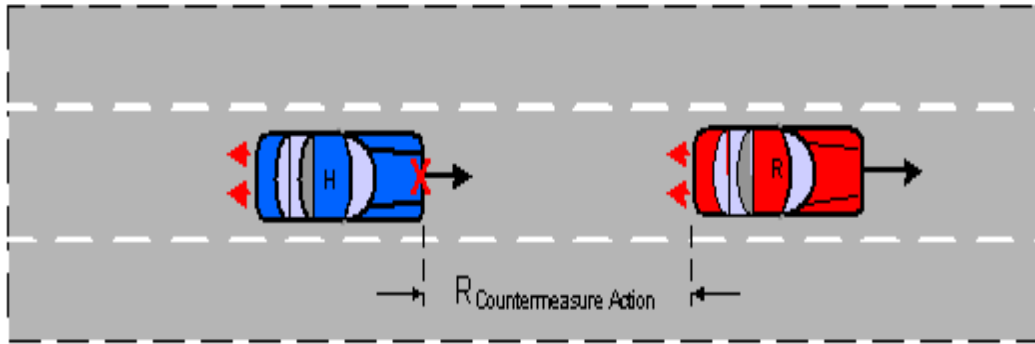
$R_{Initial}$
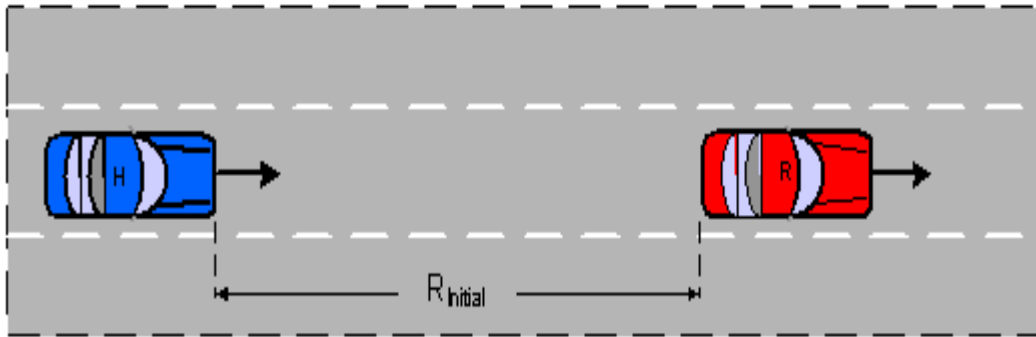
Transition

Remote vehicle begins to decelerate at a steady rate that is less than 2.0 m/sec^2

$R_{Transition}$
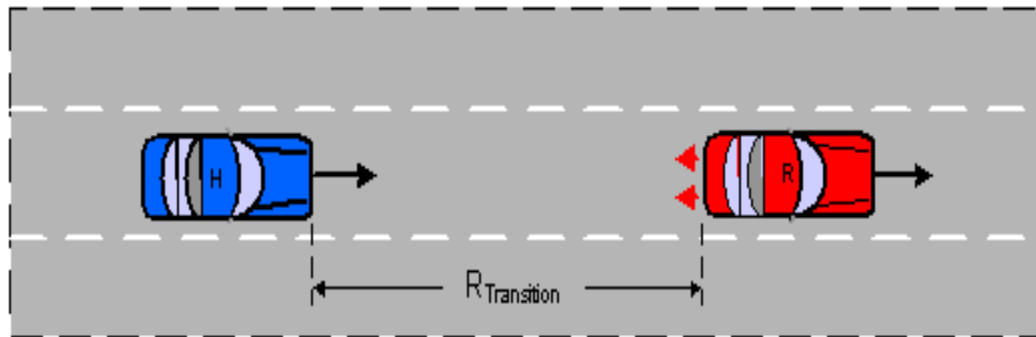
Safety Application Characterization Tests

Countermeasure Action

The countermeasure action is issued per the system specifications.

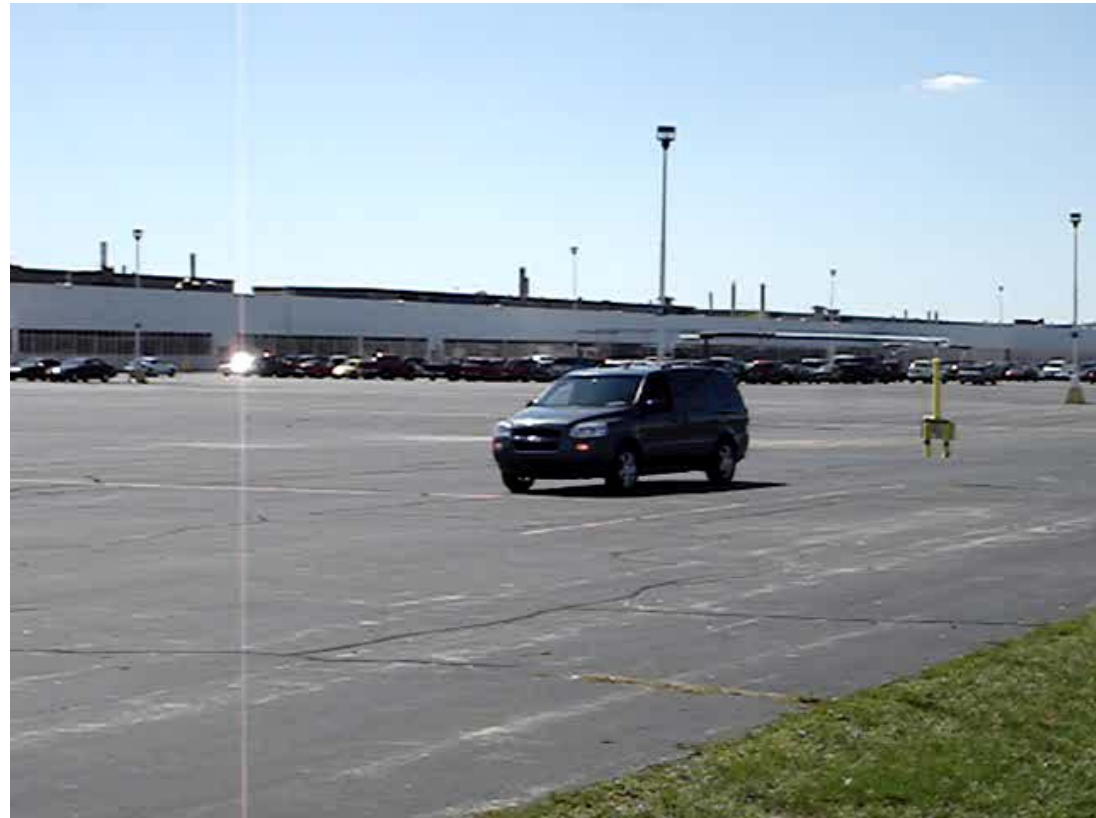$R_{\text{Countermeasure Action}}$

Resolution

After a countermeasure action or the host vehicle driver senses an imminent crash, the host vehicle shall brake and/or change lanes to avoid a collision.

$R_{\text{Resolution}}$
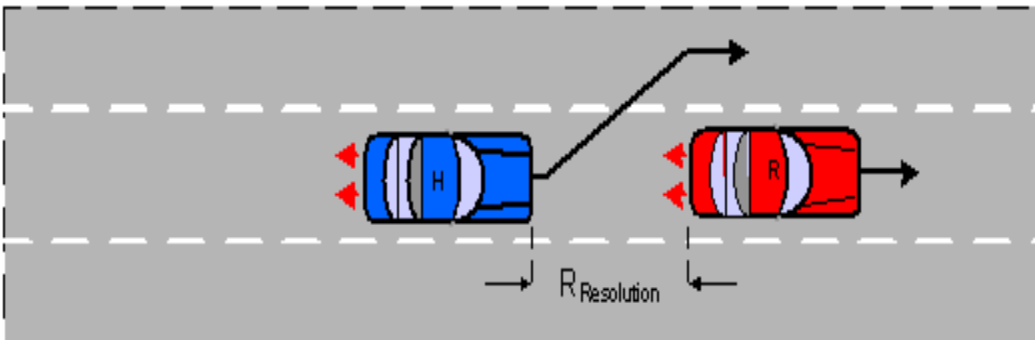
FCA Offset RV

- Position displacement
- Offset strike-able 'boom'

Intersection Surrogate Vehicle

- Examining use of a surrogate remote vehicles for use in Intersection Collision Avoidance testing.