

# **Integrated Radar-Camera Sensors: The Next Generation of Sensor Fusion**

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**DELPHI**

# Active Safety Sensor Functions

- Detect objects - "There's something out there"
- Determine salient features of the object
  - ≡ Location – "It's in front of me"
  - ≡ Range – "It's really close"
  - ≡ Range rate – "It's coming closer"
  - ≡ Size – "It's really big"
  - ≡ Classification – "It's a semi truck"
- Assess threat level – "This looks bad"
- Initiate appropriate countermeasures – "Hit the brakes!"



# Commonly Used Sensors

- Cameras (visible, thermal)
  - ≡ Best suited to detecting and identifying objects
  
- RADAR – **RA**dio **D**etection **A**nd **R**anging  
or LIDAR – **LI**ght **D**etection **A**nd **R**anging
  - ≡ Best suited to detecting and measuring range to objects

# Radar & Camera Comparison

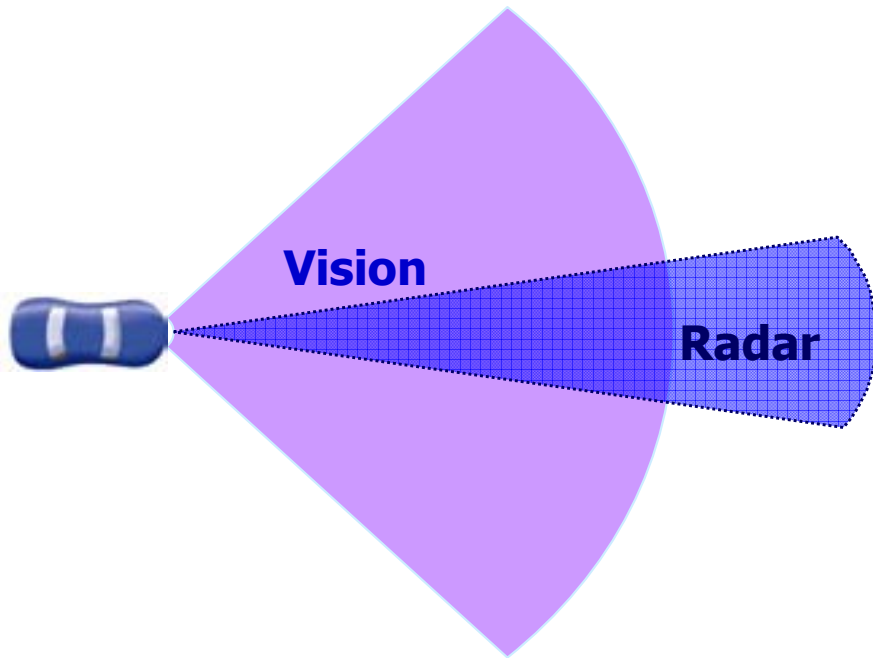
Characteristic	Radar	Camera
Target range	+	-
Range rate	+	-
Detecting objects in inclement weather	+	-
Long range operation	+	-
Target angle	-	+
Angular rate	-	+
Size or angular extent (edges)	-	+
Lane tracking	-	+
Object classification	-	+

***Sensor Fusion combines the strengths of both sensing technologies***

# Vision Enhances Radar Measurements

Vision's wide field of view enables detection of close adjacent lane vehicle

Vision's high quality angle, angular rate, edges, lane position enables cut-out vehicle to be predicted as out of path



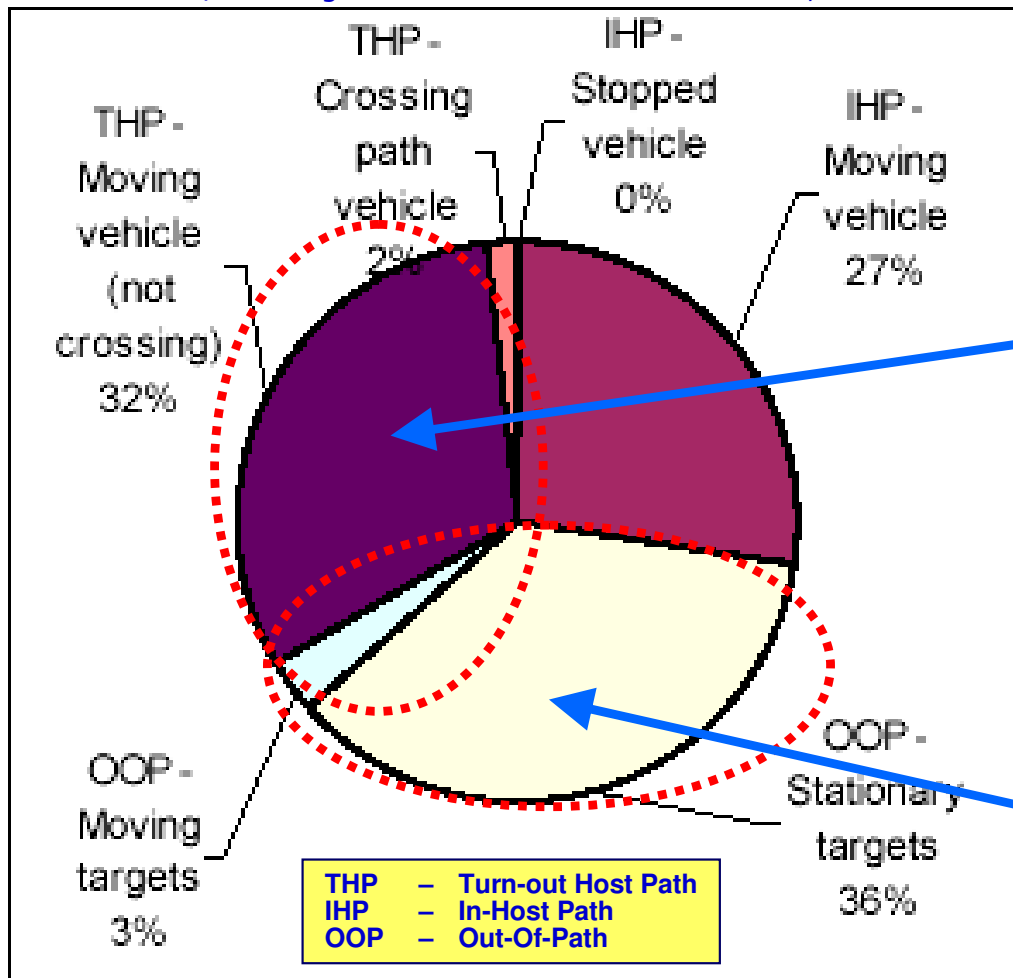
Radar field of view

Vision field of view

# Typical Radar-Only FCW Performance\*

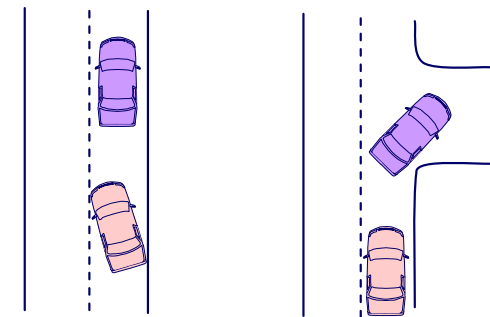
## RADAR-only FCW False Alarm Rate

\* ACAS/FOT Program results with 96 drivers over 136,000 miles

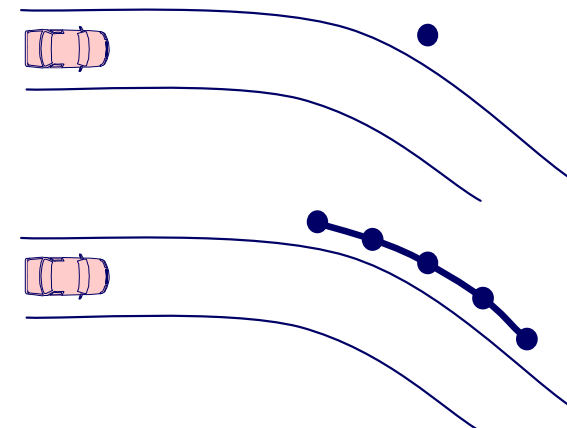


### ■ Main sources of false alarms for radar-only FCW:

≡ Transitioning Vehicles (host or lead vehicle) – 32%



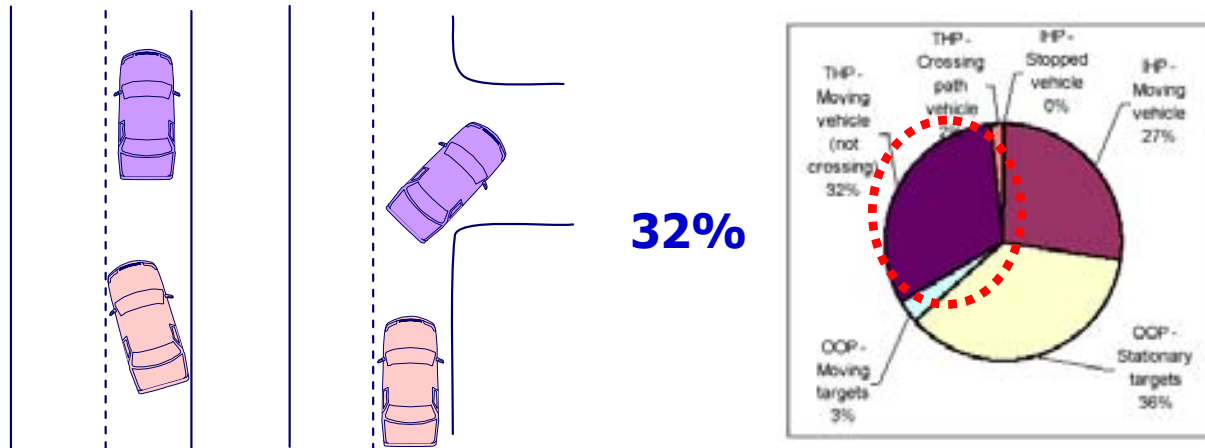
≡ Stationary Objects – 36%



# Fusion Deals with the Two Primary Sources of False Alarms

## ■ Transitioning Vehicles

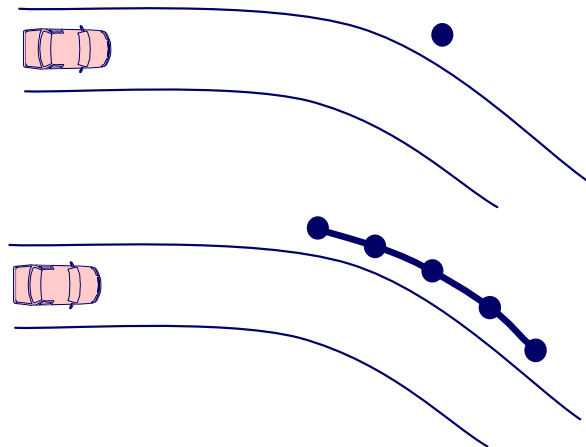
- ≡ Vision's high quality angle, angular rate, edges, lane position enables transitioning vehicle to be predicted as out of path



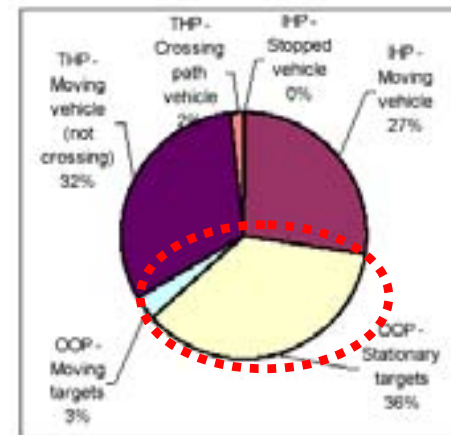
# Fusion Deals with the Two Primary Sources of False Alarms

## ■ Stationary Objects

- ≡ Lane boundaries show predicted path of the host
- ≡ Non-vehicle objects & bridges are identified



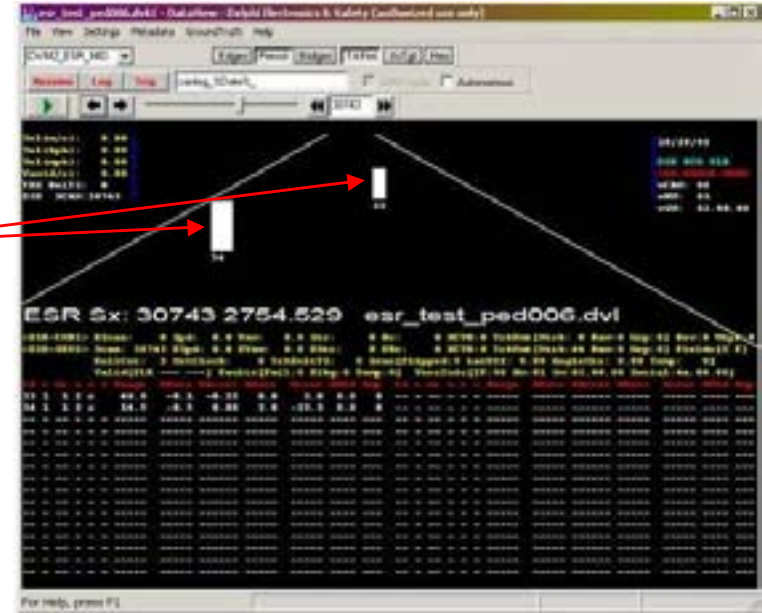
**36%**



# Fusion System Can Perform Additional Functions

- Radar cannot detect lane markers, signs, etc.

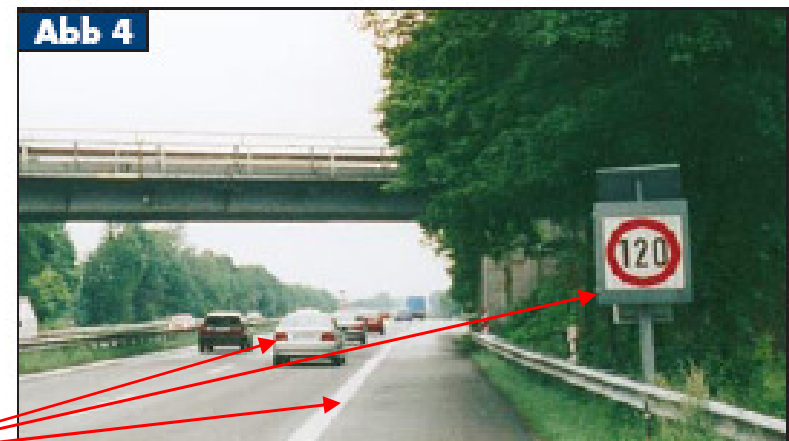
**Radar output:  
detected vehicles**



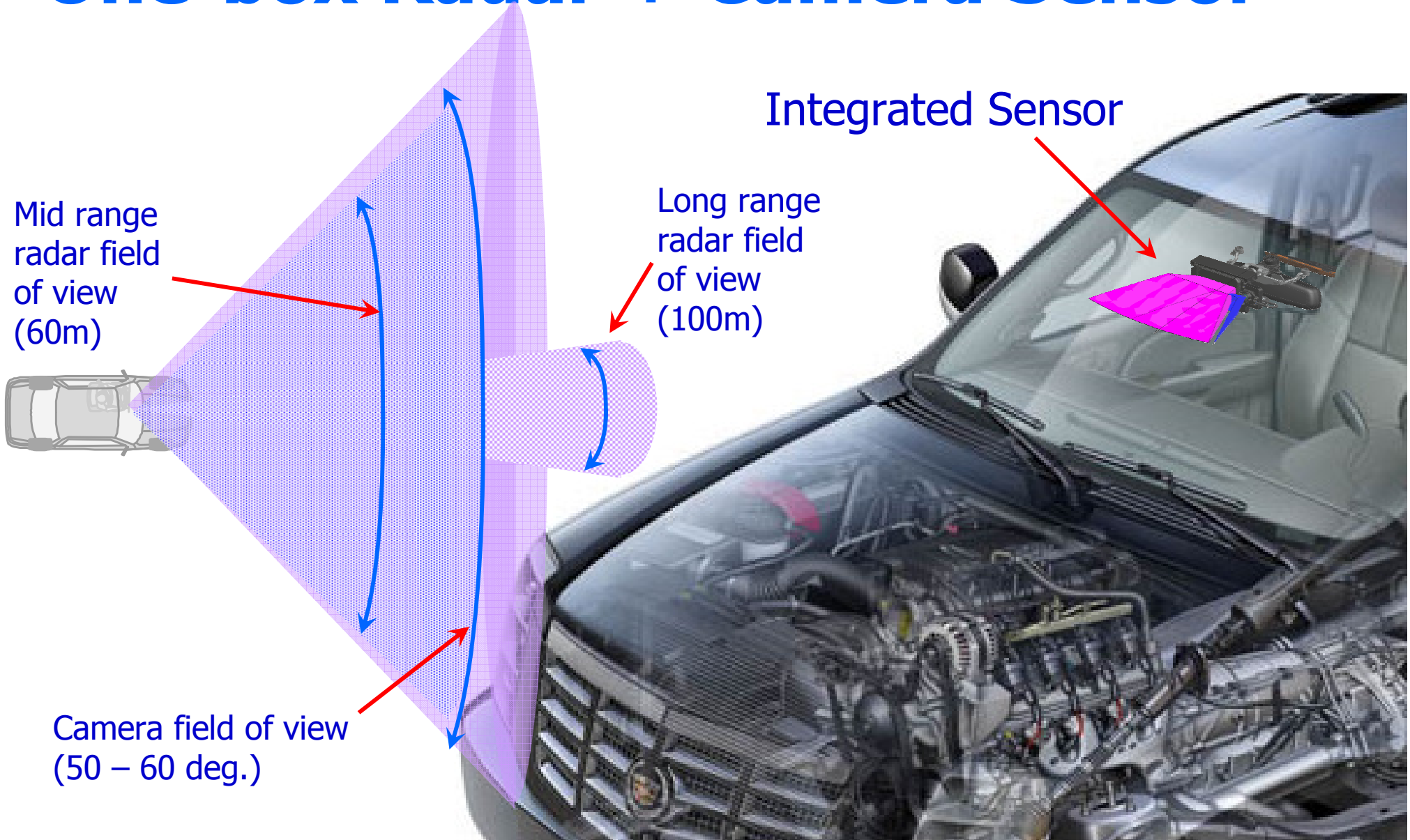
- Vision system can detect these features, enabling:

- ≡ Lane departure warning
- ≡ Sign recognition
- ≡ Headlight control

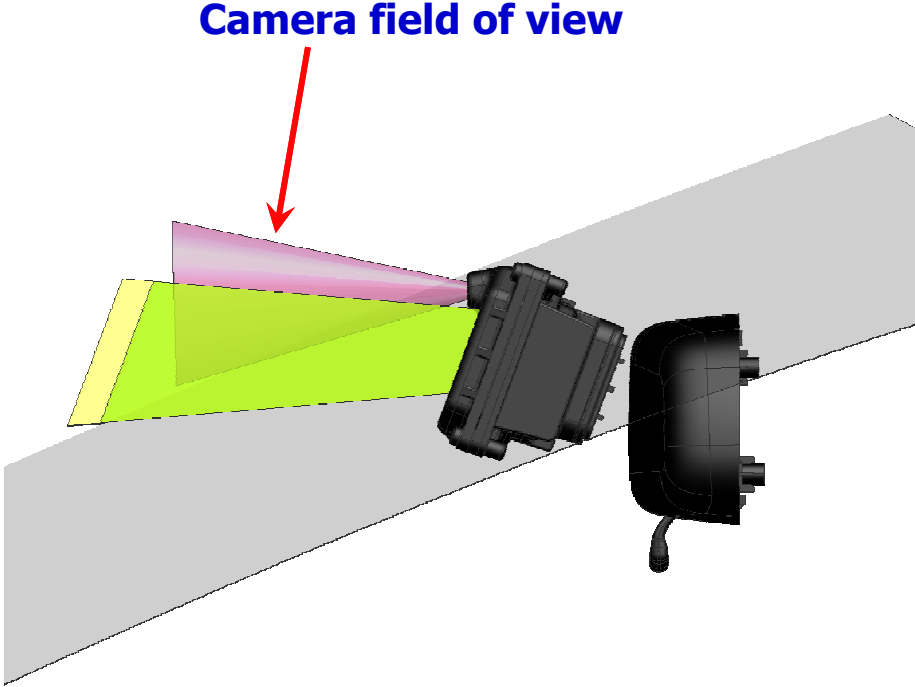
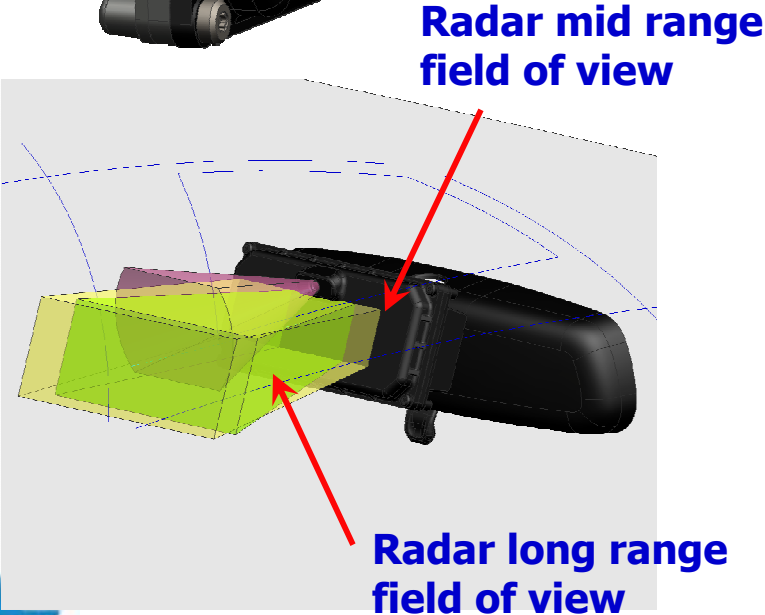
**Camera output: lane markings, signs, vehicles, etc.**



# One-box Radar + Camera Sensor



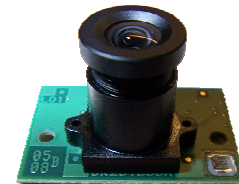
# Production Package Concept



# Sensor Configuration

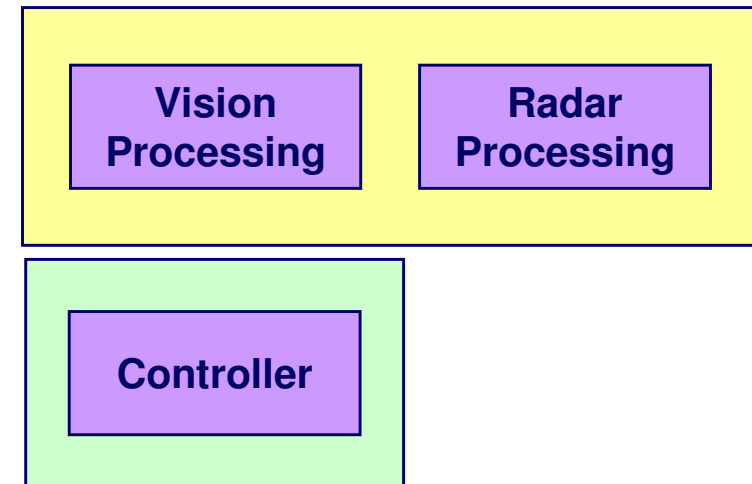
## ■ Sensors

- /// Radar: Delphi Electronically Scanned Radar variant
  - Long range: 100 m
  - Mid-range: 60 m
- /// Camera: High Dynamic Range CMOS imager



## ■ Processor Architecture

- /// Vision & Radar processor
- /// Host processor



# One-box Radar + Camera Sensor

## Advantages

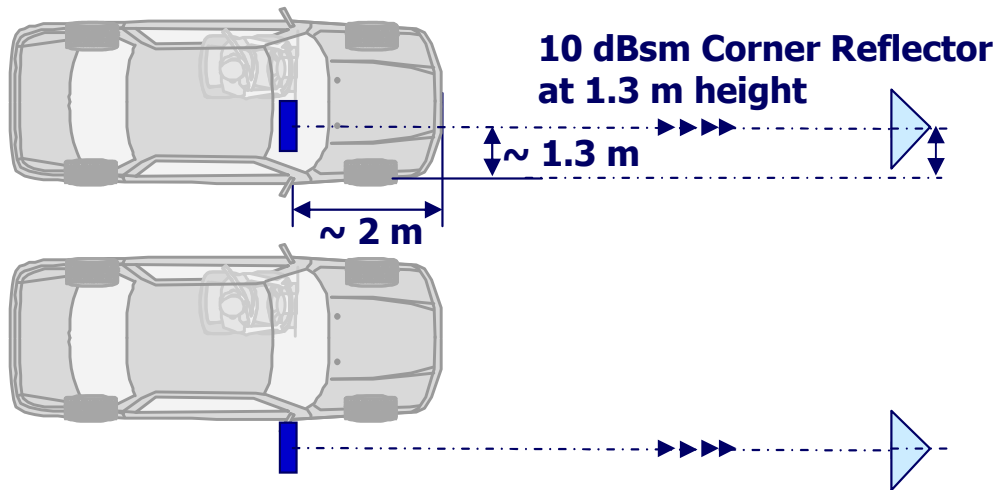
- Fusion provides improved performance and reduced false alarm rate
- Three separate units combined into one
  - ≡ Camera
  - ≡ Radar
  - ≡ Driver Assistance function processor
- Reduced cost due to shared elements (e.g. power supplies, CPU, packaging)
- Smaller total volume
- Sensor is moved away from the bumper, reducing insurance replacement costs

## Disadvantages

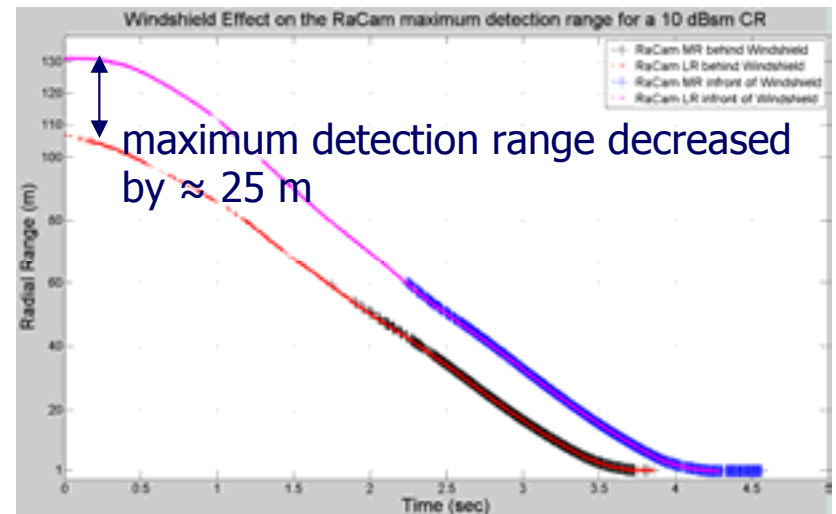
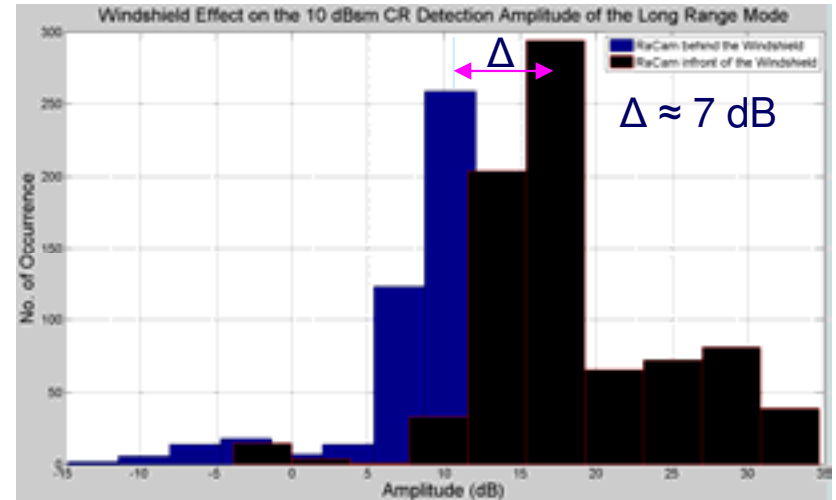
- Windshield space is at a premium
- Added mass in rearview mirror area

# Impact of Windshield on Radar Sensitivity

## Test setup



- Windshield two-way loss  $\approx 7$  dB
  - ≡ For both long and mid-range
- Maximum detection range reduction  $\approx 25$  m



# Issues

## ■ Windshield Transmissivity

- ≡ 100 m range is short for ACC
  - Actual vehicle tests show up to 130 m range detection
- ≡ New CARB regulations may result in metallized windshields
  - Radar tests are underway

## ■ RADAR in the passenger compartment

- ≡ Radar complies with the FCC (NCRP) limit for long term exposure directly in front of the radar for stand off distance of at least 3.7cm
- ≡ Measured radar power density is significantly less than cell phones and other wireless devices

**Thank you!**

