Object Fusion for an Advanced Emergency Braking System (AEBS)

2015-09-24 Jonny Andersson

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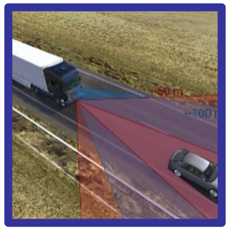
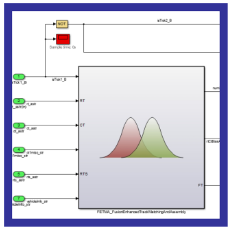
Agenda

1. Rear-end collisions & EU legislation

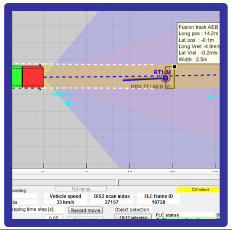
2. How the AEB system works



3. Object fusion methods



4. Simulink implementation



5. Sensor visualisation and testing tools

Rear-end collisions & Legislation

- Rear-end collisions most common accident types for heavy vehicles

- AEB regulated on heavy trucks and buses in the EU from:
  - Nov. 2013 – for new types
  - Nov. 2015 – for new vehicles

The result of a ”trailerback” accident

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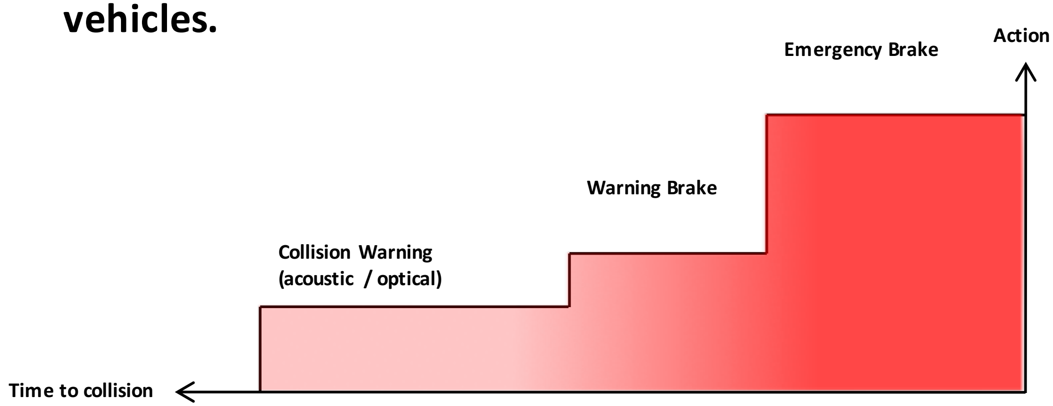
How AEB works
(Advanced Emergency Brake)

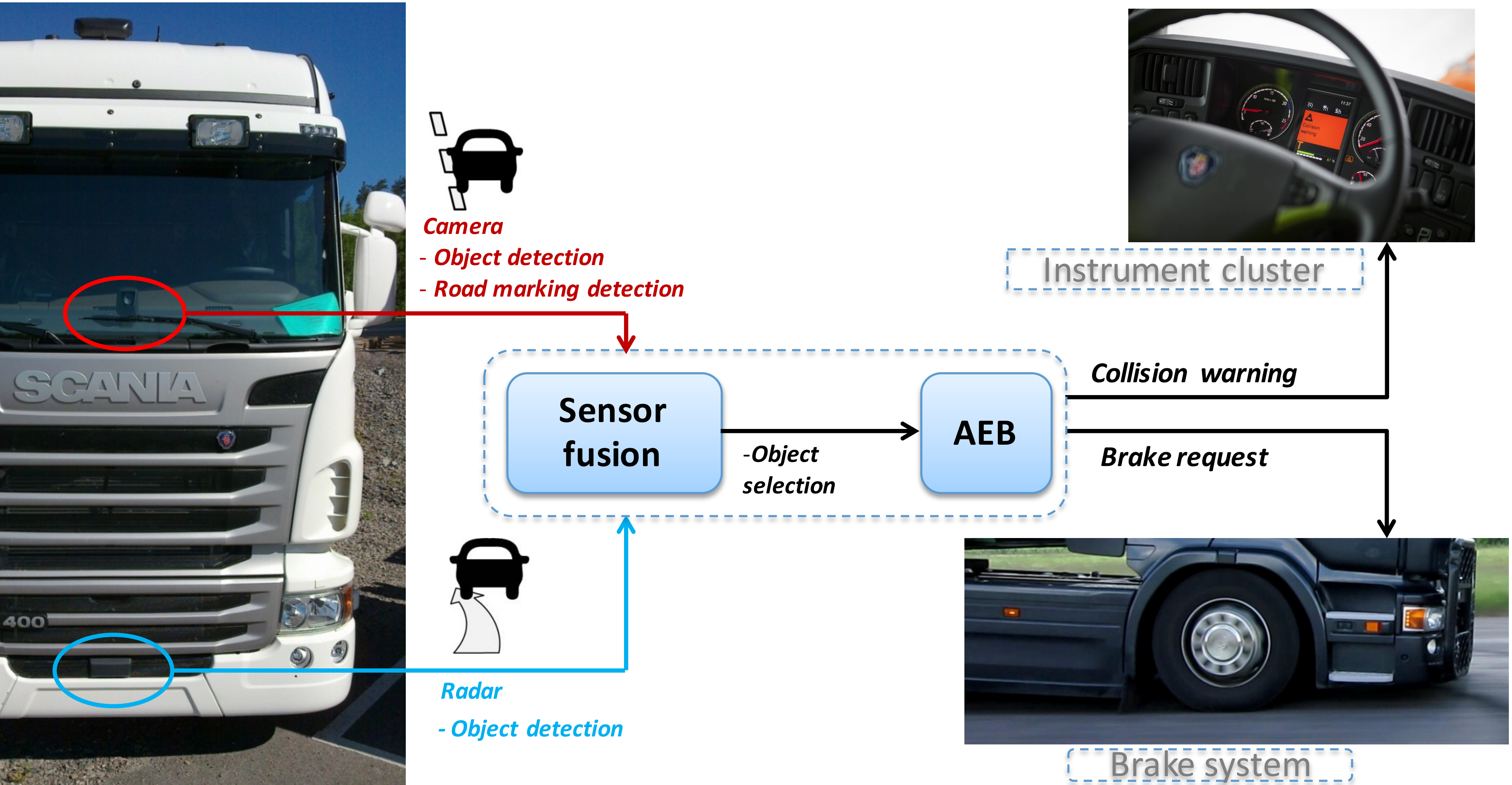
At risk of collision:

- **Collision warning**
  - → **If no driver reaction:**
- **Warning brake** **(- 3 m/s^2)**
  - → **If no driver reaction:**
- **Emergency brake (full brake ~6-7m/s^2)**

- **Avoidance for <u>moving</u> target vehicles**
- **Attempting avoidance also for <u>stationary</u> vehicles.**



How AEB works
(Advanced Emergency Brake)



AEB (Advanced Emergency Brake)

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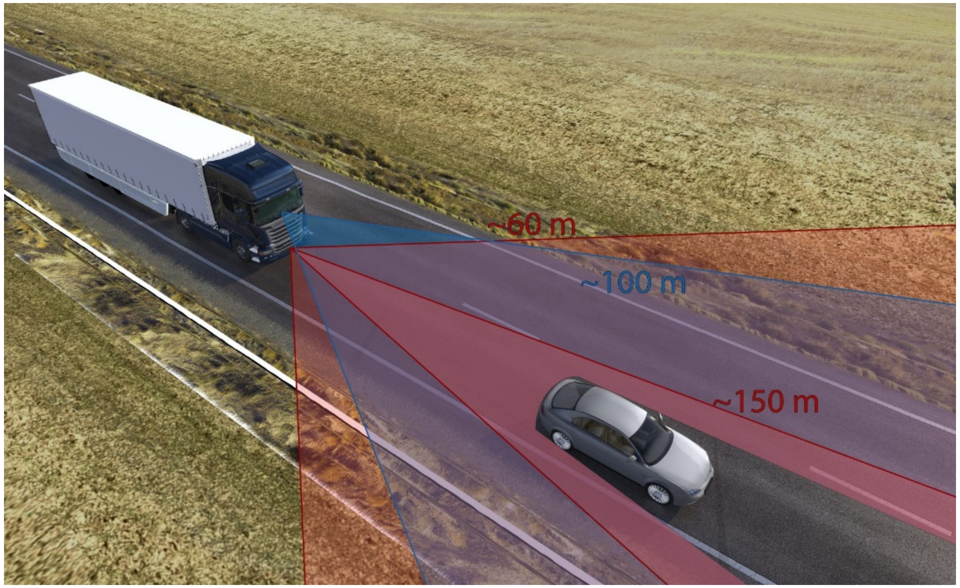
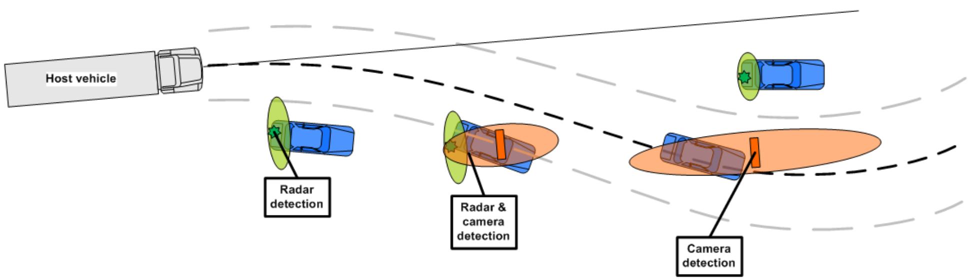
Sensor fusion
Two sensors -> One ”truth”



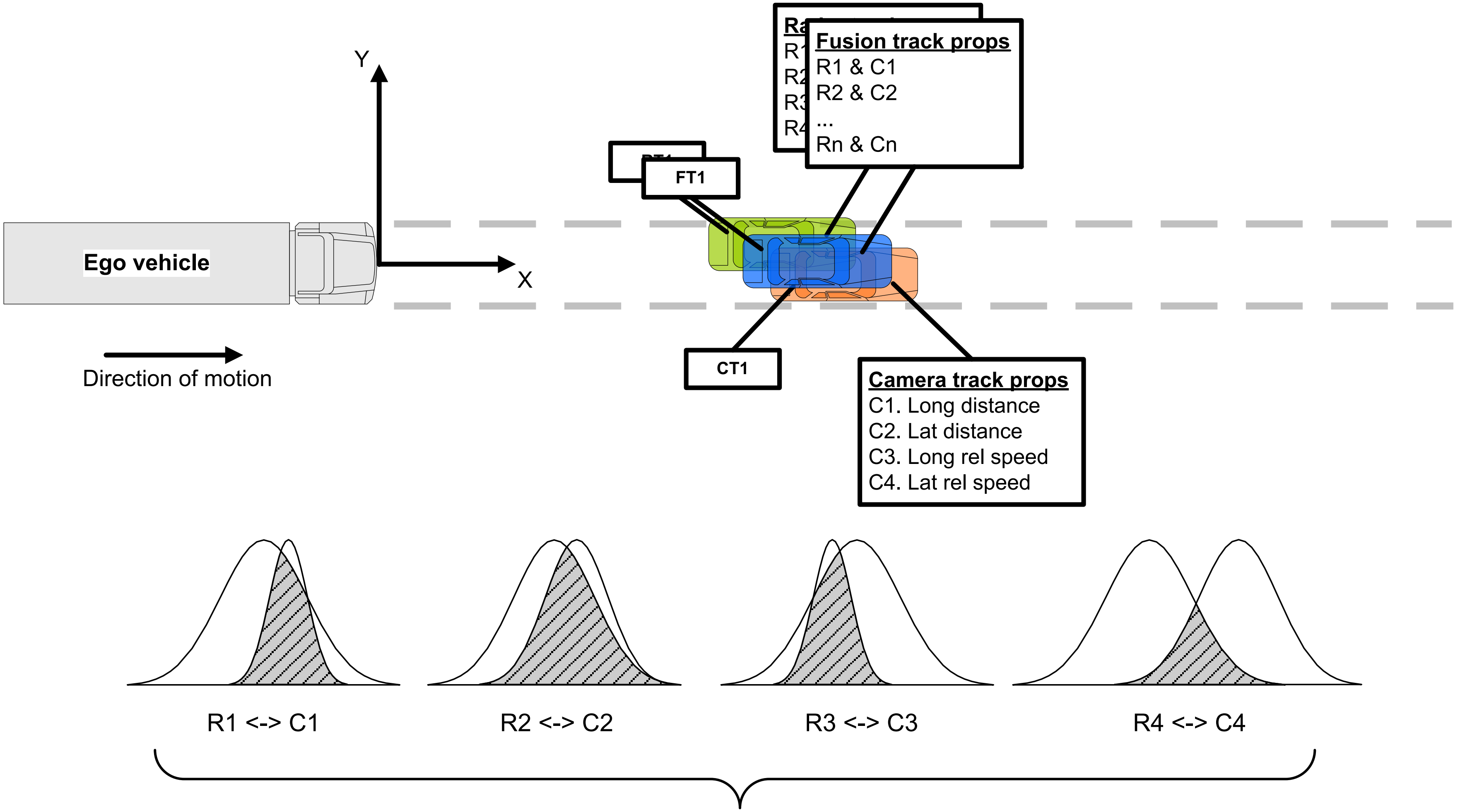


Sensors have different advantages

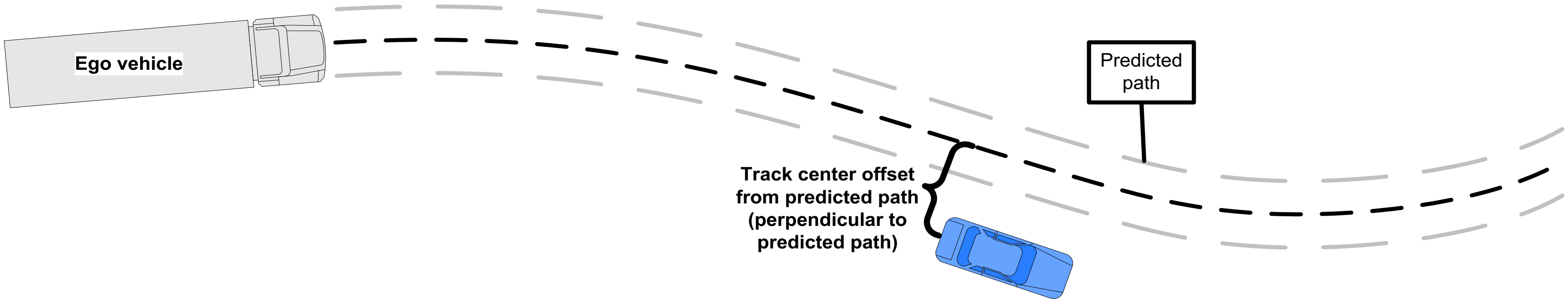
- Radar
  - \+ Range (longitudinal)
  - \+ Relative velocity
  - \+ Solid object reflection
  - \- No shapes
  - \- Lateral position
- Camera
  - \+ Object type
  - \+ Object width
  - \+ Lateral position
  - \- Range
  - \- Optical illusions

Redundance required for stationary objects

Matching and merging



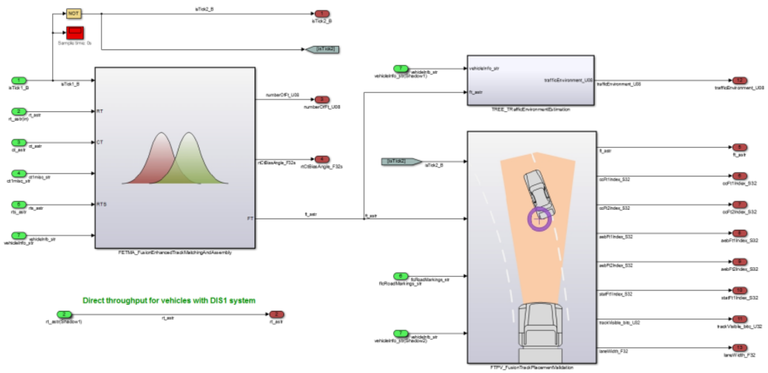
Object selection



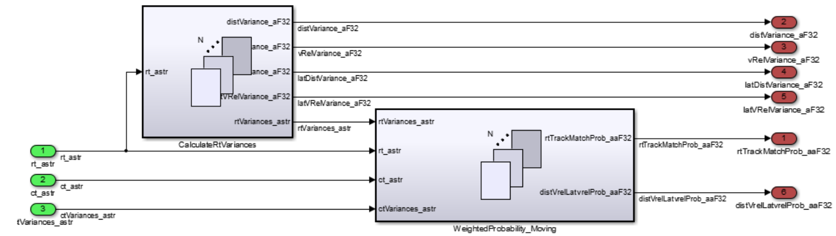
- Object position compared to a ”predicted path”
- Relative speeds from/away from predicted path for cut-in/cut-out
- Different selection zones for AEB and ACC
  - ⇨ AEB has narrower field of interest than ACC
  - ⇨ The selection criteria of objects reported to AEB and ACC differ

Model Based Design for fusion

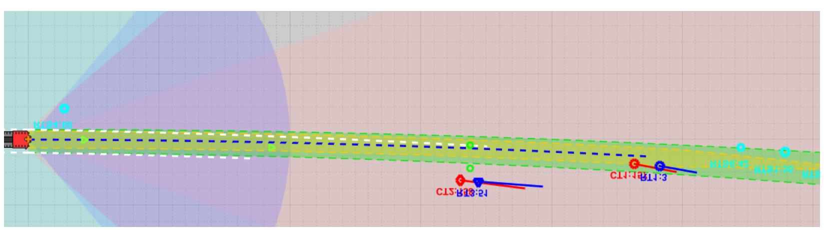
Easy to get nice and readable architecture



For-each systems and Matlab Function blocks, suitable for loops and similar calculations.



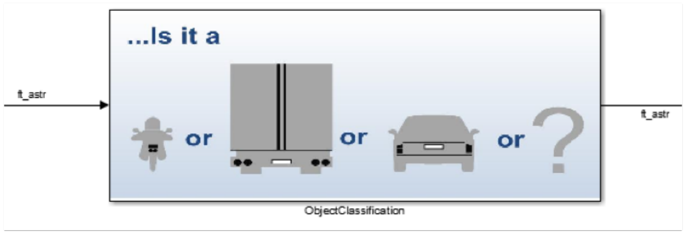
MATLAB is a suitable platform for debugging and visualization.



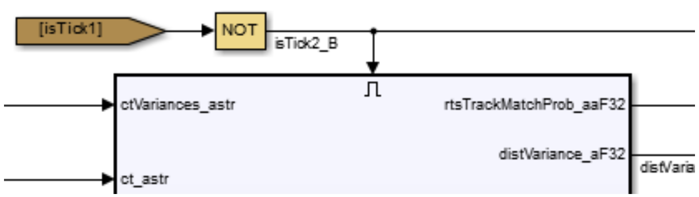
Easy debugging in Matlab Function Block

```
%%  3. Calculate zone-placement (canditates for validation)
% Proceed if the track is a single DIS track or "better". Single camera tracks are not let through here.

% Track valid, get its path offset and movement status.
offsetPredPathSquared_F32          = ft_astr(track_S32).instOffsetPredPathSquared_F32;
predOffsetPredPathSquared_F32      = ft_astr(track_S32).predOffsetPredPathSquared_F32;

mainZoneLeftSquared_F32 = mainTrackZone_aF32(track_S32)*mainTrackZone_aF32(track_S32);
mainZoneRightSquared_F32 = -mainZoneLeftSquared_F32;

```

Code generation optimization: Solutions



Problem: Data copies of bus-arrays are extremely expensive
Solution: *Signal objects used to force reuse the data*



Problem: Execution time too long for ECU
Solution: *Model divided into two ticks – probabilites calculated only every 2 ticks.*

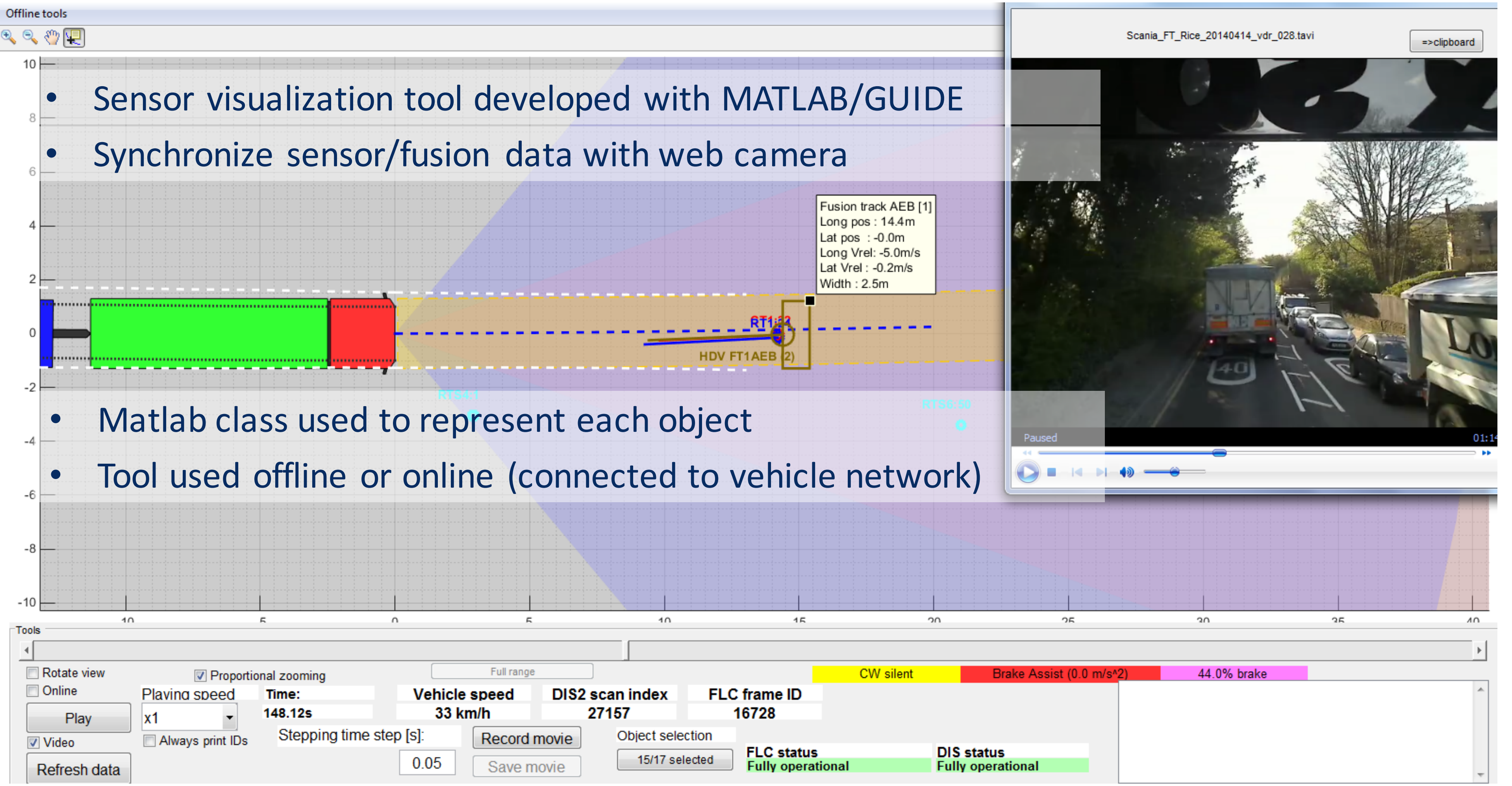
```
coder.ceval('Mbd_approxSqrt_F32',x_F32);
```

$$\sqrt{x} \sim f(x)$$

Problem: Trigonometric functions are expensive on target HW
Solution: *Trigonometric approximations. coder.ceval used for hand-coded functions.*

Sensor Visualization

- Sensor visualization tool developed with MATLAB/GUIDE
- Synchronize sensor/fusion data with web camera



- Matlab class used to represent each object
- Tool used offline or online (connected to vehicle network)

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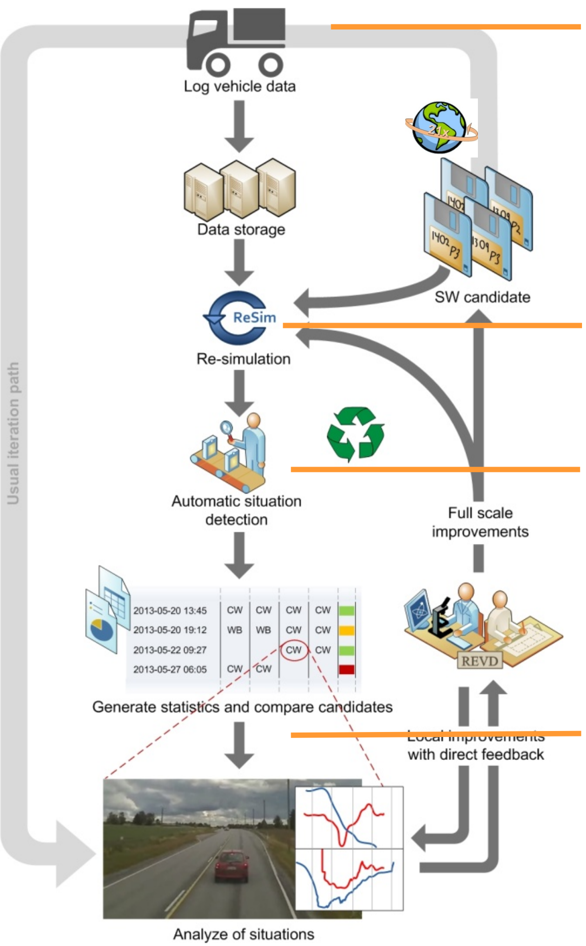
Development workflow

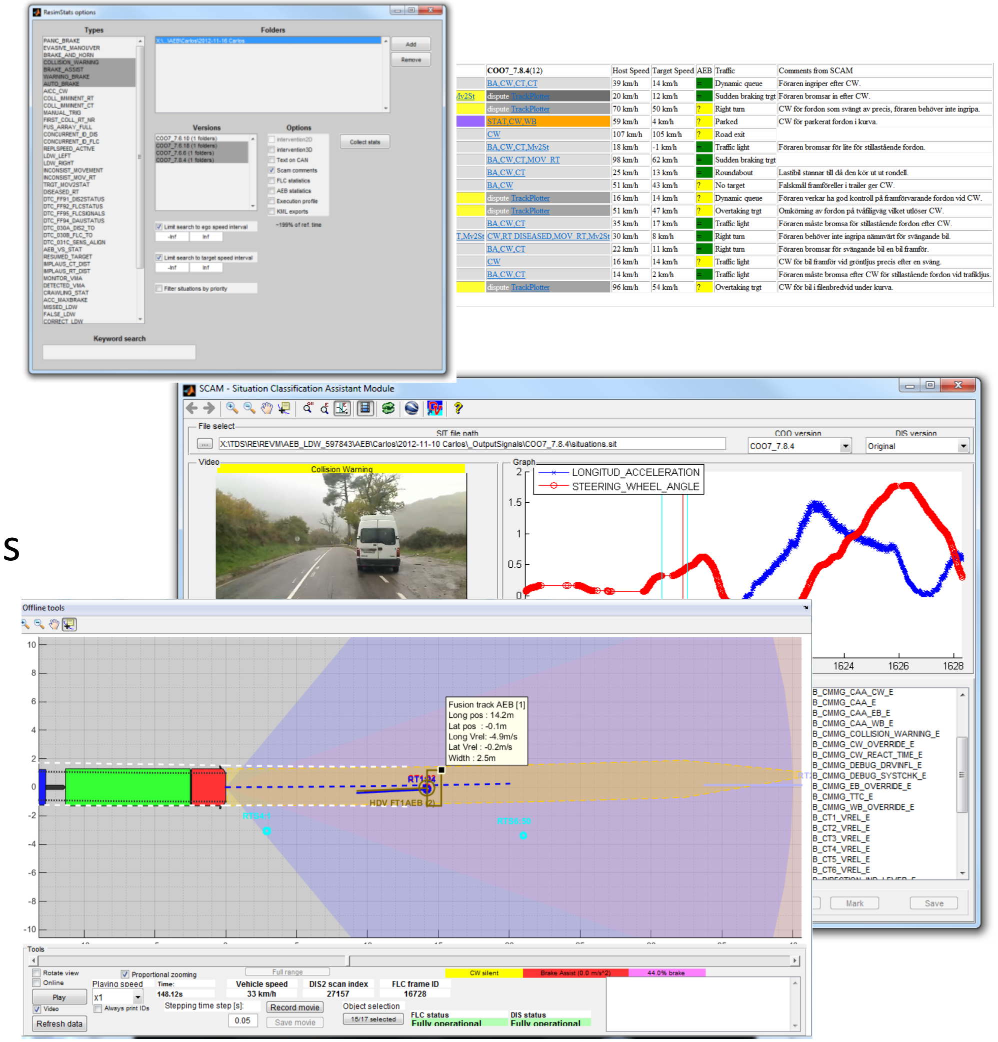


1. Gather data

2. Re-simulate

3. Find situations

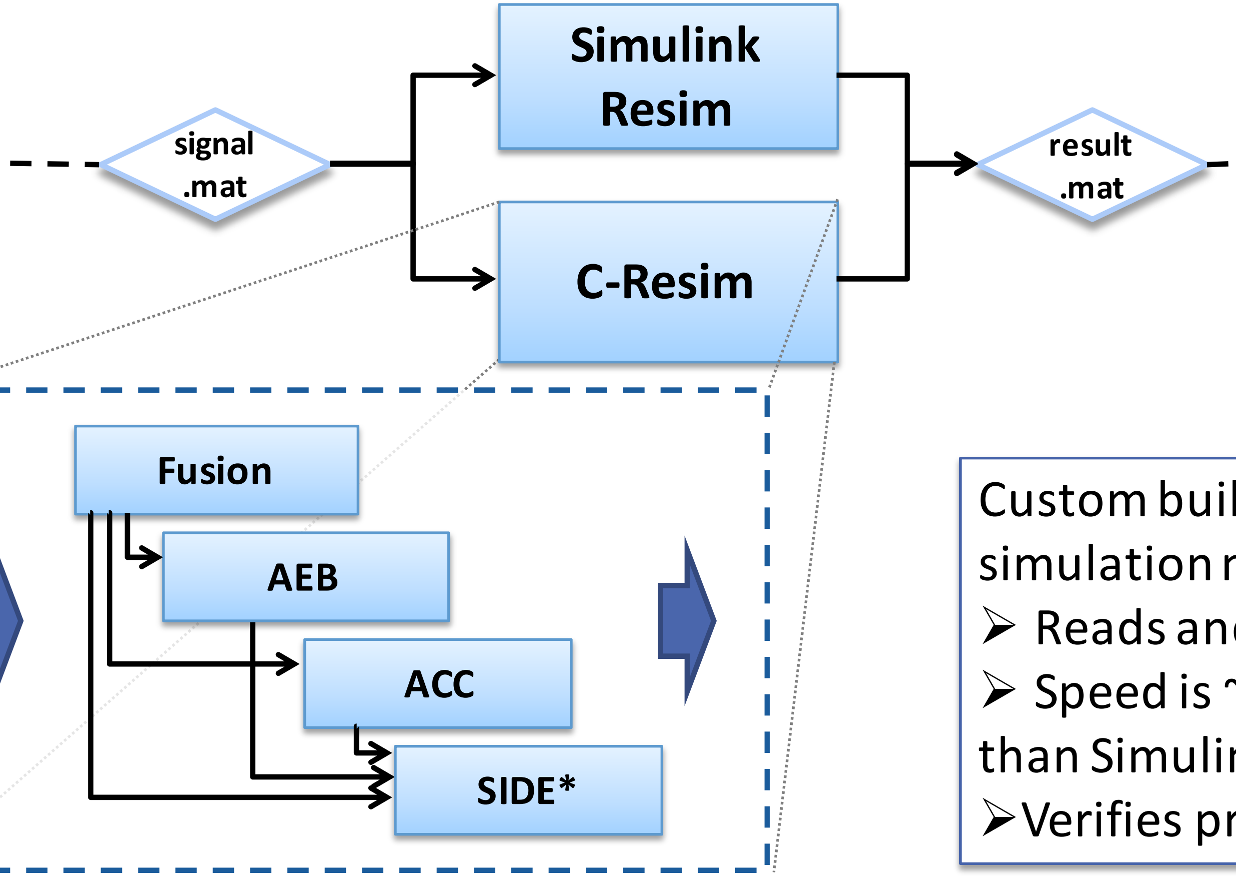
4. Classify and analyze



Data gathering

- Record ALL required data for the system to work continuously together with a reference camera.
- Need for **real traffic data** for negative testing is **massive**.

Re-simulation (1)

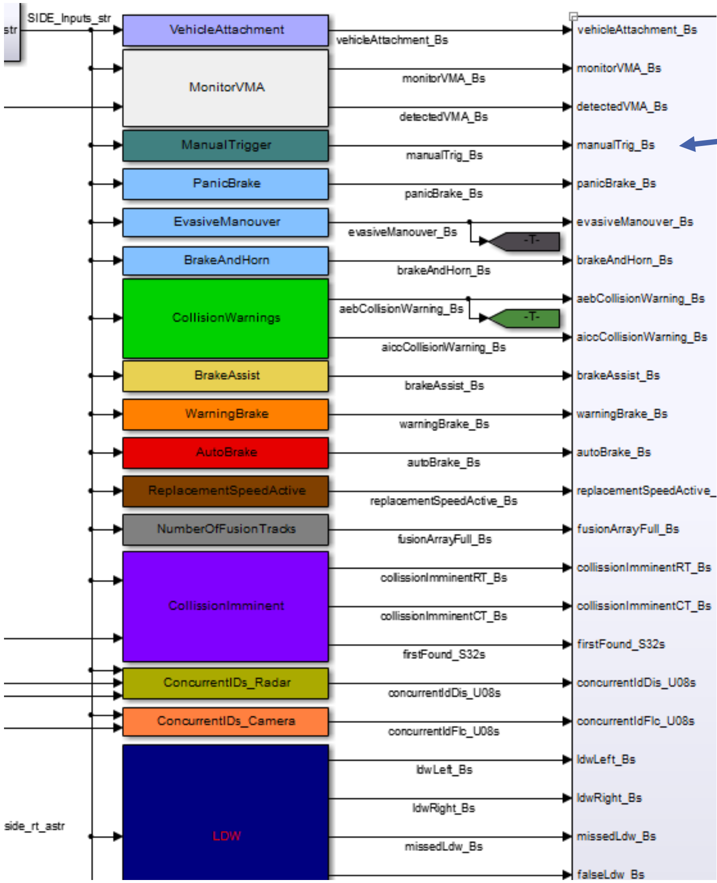


*SIDE = Situation Identification

Custom built emulator for the simulation need.

- Reads and writes mat-files
- Speed is ~150 times faster than Simulink.
- Verifies production code

Situation detection



Finding situations in the data

- Events from simulation
- Interesting situations
- Problems with sensors
- …

Compare SW versions

	Scan	COO7_7.6.18(17)	COO7_7.8.4(12)	Host Speed	Target Speed	AEB	Traffic	Comments from SCAM
5.72s)	55346	BA,CW,CT,CT	BA,CW,CT,CT	39 km/h	14 km/h	=	Dynamic queue	Föraren ingriper efter CW.
5.28s)	47603	BA,CW,CT,RT DISEASED,Mv2St	dispute TrackPlotter	20 km/h	12 km/h	=	Sudden braking trgt	Föraren bromsar in efter CW.
3.87s)	61868	CW	dispute TrackPlotter	70 km/h	50 km/h	?	Right turn	CW för fordon som svängt av precis, föraren behöver in
2.71s)	3312	STAT,CW	STAT,CW,WB	59 km/h	4 km/h	?	Parked	CW för parkerat fordon i kurva.
4.93s)	62236	CW	CW	107 km/h	105 km/h	?	Road exit	
	30755	BA,CW,CT,Mv2St	BA,CW,CT,Mv2St	18 km/h	-1 km/h	=	Traffic light	Föraren bromsar för lite för stillastående fordon.
2s)	56083	BA,CW,CT,MOV_RT	BA,CW,CT,MOV_RT	98 km/h	62 km/h	=	Sudden braking trgt	
3s)	34994	BA,CW,CT	BA,CW,CT	25 km/h	13 km/h	=	Roundabout	Lastibil stannar till då den kör ut ut rondell.
3s)	9209	BA,CW	BA,CW	51 km/h	43 km/h	?	No target	Falskmål framföreller i trailer ger CW.
5s)	33362	CW,Mv2St	dispute TrackPlotter	16 km/h	14 km/h	?	Dynamic queue	Föraren verkar ha god kontroll på framförvarande fordo
4s)	36343	CW	dispute TrackPlotter	51 km/h	47 km/h	?	Overtaking trgt	Omkörning av fordon på tvåfiligväg vilket utlöser CW.
7s)	34524	BA,CW,CT	BA,CW,CT	35 km/h	17 km/h	=	Traffic light	Föraren måste bromsa för stillastående fordon efter CW
	30535	CW,RT DISEASED,MOV_RT,Mv2St	CW,RT DISEASED,MOV_RT,Mv2St	30 km/h	8 km/h	=	Right turn	Föraren behöver inte ingripa nämnvärt för svängande bil.
5s)	39796	BA,CW,CT	BA,CW,CT	22 km/h	11 km/h	=	Right turn	Föraren bromsar för svängande bil en bil framför.

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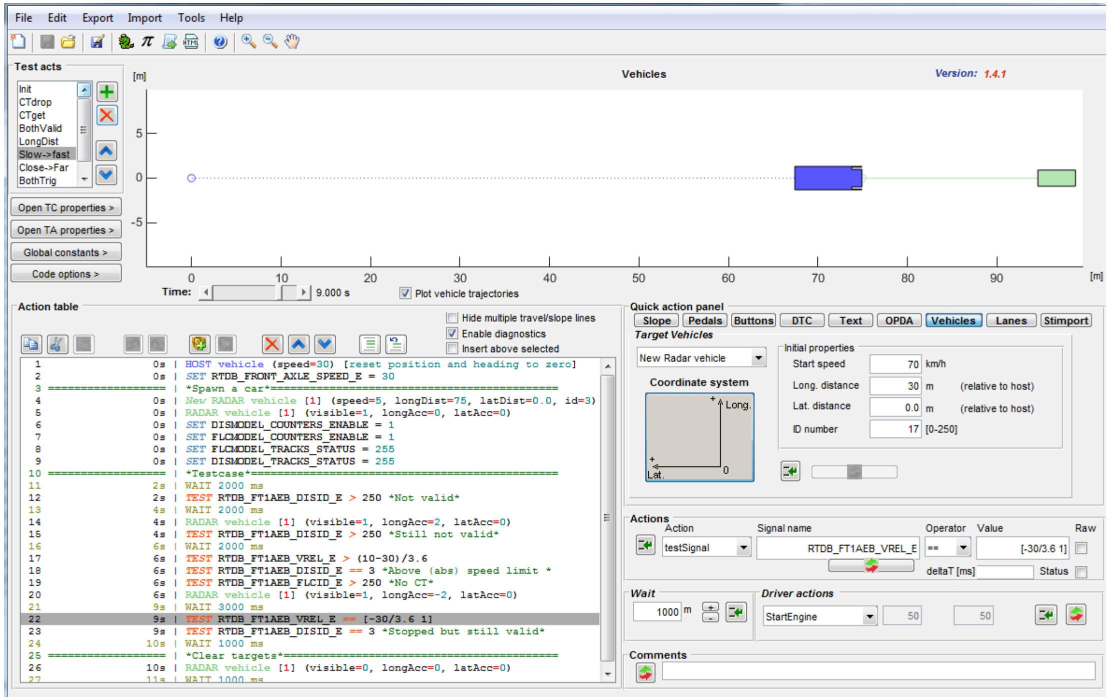
Regression testing

- Test scenario creation tool suitable to design test cases visually.
- Can run same test cases in
  - Simulink
  - C-Resim
  - HIL



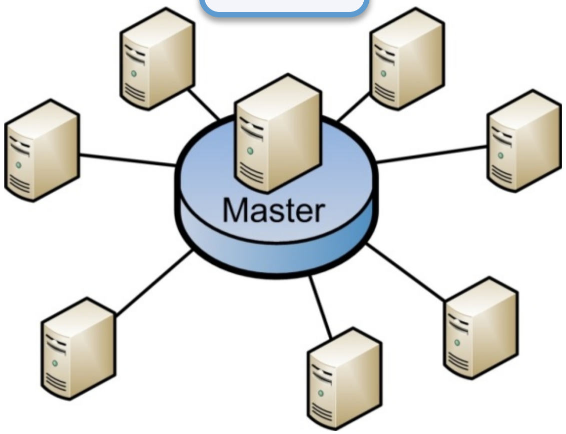
Simulation cluster

1 500 000 km

80 TB

... in 12h

- Speed is increased by separating the job into **parallel tasks** and distribute them **over the network** with the help of **MATLAB**
- A master node coordinates the job while client nodes offer their computational capacity. New nodes can join in during



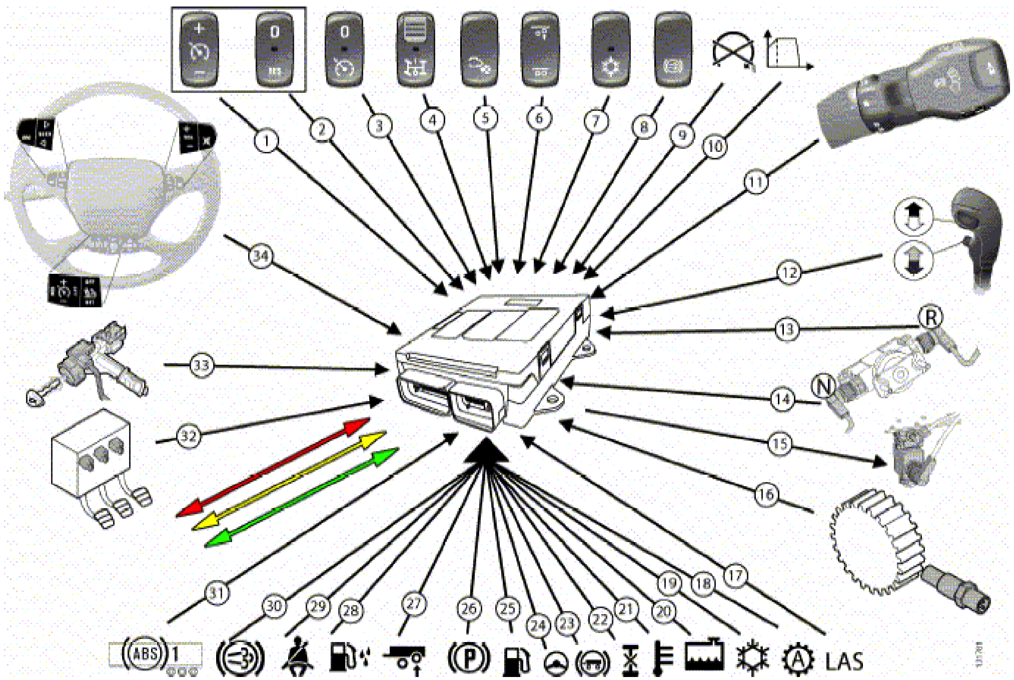
Simulation method	Relative simulation speed
Simulink-simulation (AEB)	0.25 x real-time
C-resim (AEB)	40 x real-time
Distributed C-resim (AEB)	N x 40 x real-time

Thank you!

Summary

- Visualization of sensor data – key to understanding any scenario.
- Development by ”Massive simulation” - enhances quality and confidence of active safety functionality.
- (Fast simulations are necessary to achieve the above)
- Mathworks tools have successfully supported this workflow

Target ECU Hardware (2013)



ECU Hardware	
CPU	132MHz (floating point support)
RAM	64kByte + 512kByte (external)
Flash	1Mb
E2	64kByte
CPU load	~60% before introduction of AEB and fusion

ECU designed for I/O, gateway and simple functions.

Not optimized for massive calculations!