Automotive Radars Challenges and Requirements

Igal Bilik (Advanced Technical Center, GM Israel)
Igal.Bilik@gm.com
Shahar Villeval (Advanced Technical Center, GM, Israel)

For decades, self-driving cars were a futuristic concept...

Source: Jürgen Hildebrandt, Dr.-Ing. Martin Kunert, Bernhard Lucas, Dr. Thomas Classen, "Sensor Setups for future Driver Assistance and Automated Driving," Bosch, IWPC Workshop2013.

History of Autonomous Driving

"Futurama" by GM in 1939 New York worlds fair:
20 years future envision: Automated highway system with longitudinal and lateral vehicle control.

The 1958 Chevrolet Impala with "Unicontrol."

What traveling in an automated vehicle might be like (1997)

Source: Jameson M. Wetmore Consortium for Science, Policy & Outcomes Arizona State University, *Automotive History Review, Summer 2003, pp. 4-19,* http://www.cspo.org/documents/article_Wetmore-DrivingTheDream.pdf

Tomorrow is Here
CES 2016: Autonomous Driving

Google

Tesla

Mersedes

Volvo

Toyota

GM

Recent OEMs Announcements

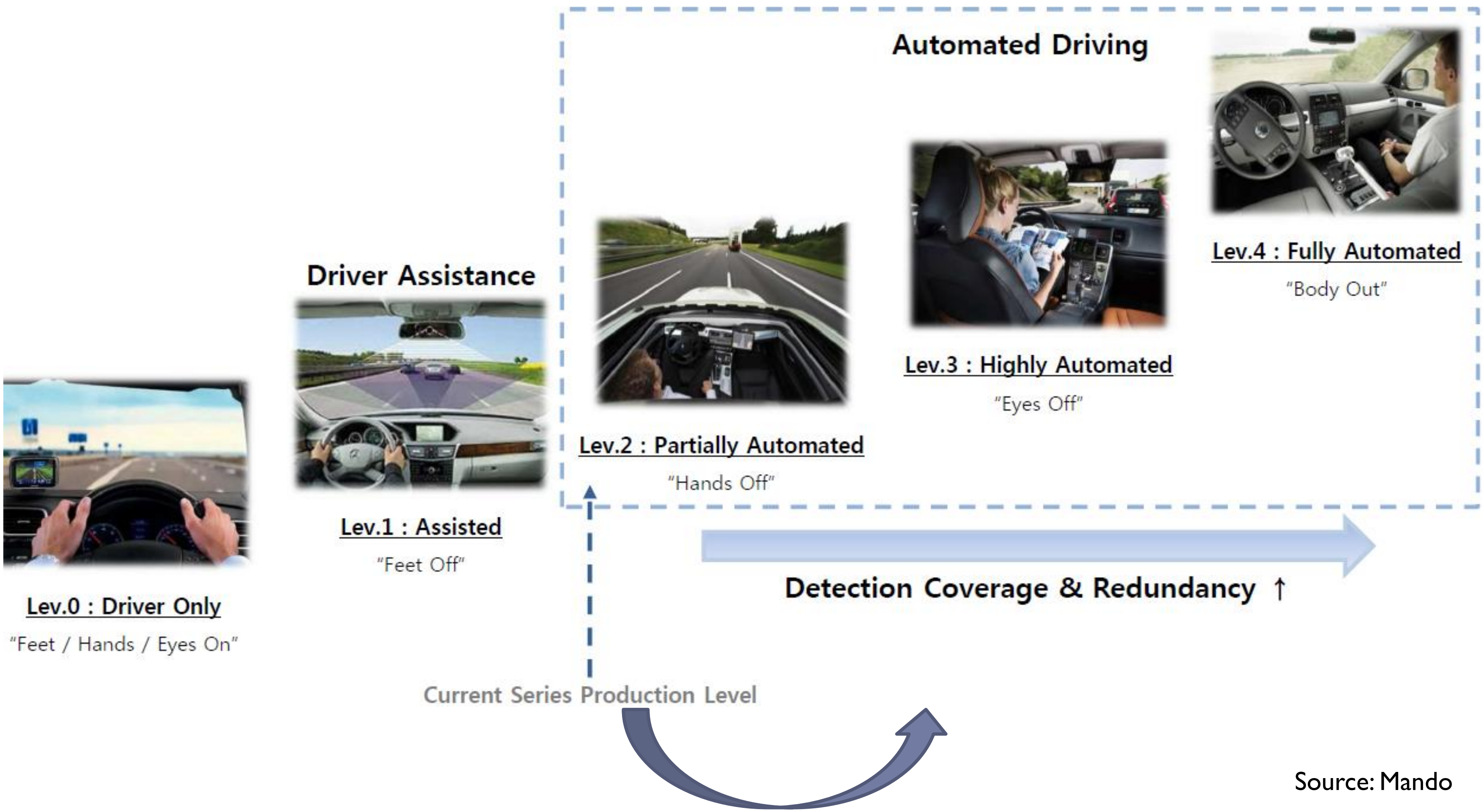
Announcements for 2015-2016

Mercedes-Benz	Mercedes plans to introduce "Autobahn Pilot"...the system allows hands-free highway driving..."it can also pass other vehicles without the need for the driver to use the steering wheel" – Autoevolution
General Motors	"GM is to offer what it is calling 'Super Cruise' in a new Cadillac model".... "System will allow the car to automatically keep its lane, autonomously trigger braking and speed control" – The Los Angeles Times
Tesla Motors	"Tesla Motors Inc. plans to offer hands-free highway driving in its Model S electric sedans in 2015" – The Wall Street Journal
Audi	"Audi AG plans to roll out technology to enable autonomous driving in urban traffic" – Bloomberg News
Mobileye	Mobileye...is planning to launch, in the 2016 time frame and with two partner OEMs, the first hands-free capable driving at highway speeds and in congested traffic situations" – Mobileye website

Source: Press reports, BCG research

GM Autonomous Demos

Automation Levels



Source: Mando

Jump in Capabilities

Technology Enablers for Autonomous Driving

Sensing →	**What's around me?**	360° sensing and perception
Mapping →	**Where am I?**	High accuracy positioning High definition maps
Planning →	**Take me where I want to go**	Navigation Motion planning Controls & Actuators
Monitoring →	**Who is in charge?**	Vehicle health monitoring Driver monitoring

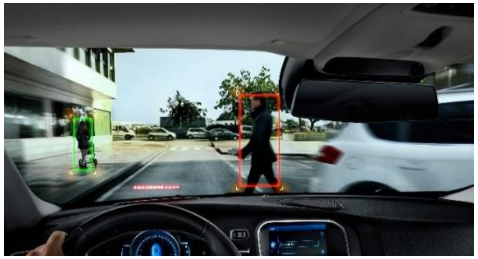
From Dr. Ran Gazit presentation, ATCI, GM

Sensing for Autonomous Driving

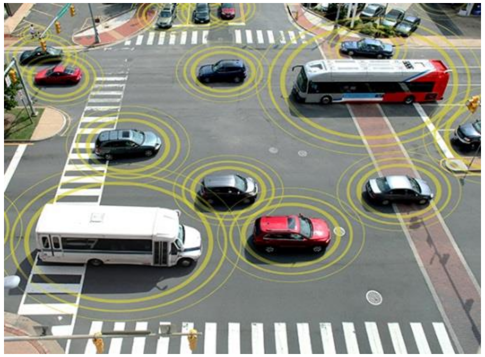
Sensing → **What's around me?**

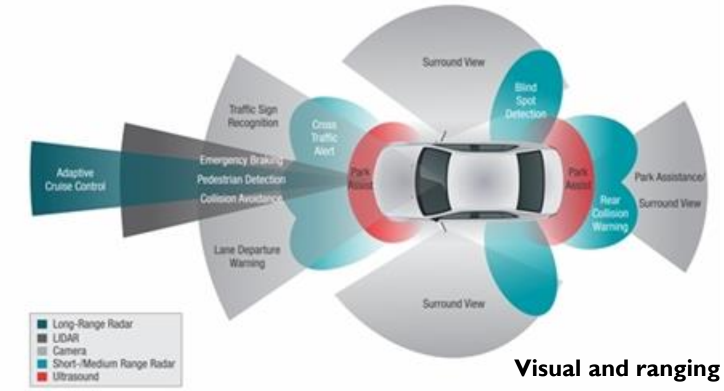
360° sensing	*Examples*
• **Visual**	*Cameras, Night vision*
• **Ranging**	*Radar, Lidar, Stereo*
• **Connectivity**	*V2V, V2I, OnStar*
Perception	
• **Situational awareness**	*Relative position and velocity of vehicles and pedestrians, pothole location, …*
• **Scene understanding**	*Pedestrian is walking towards road crossing, vehicle is on exit lane, potholes expected in my lane…*

Visual pedestrian detection



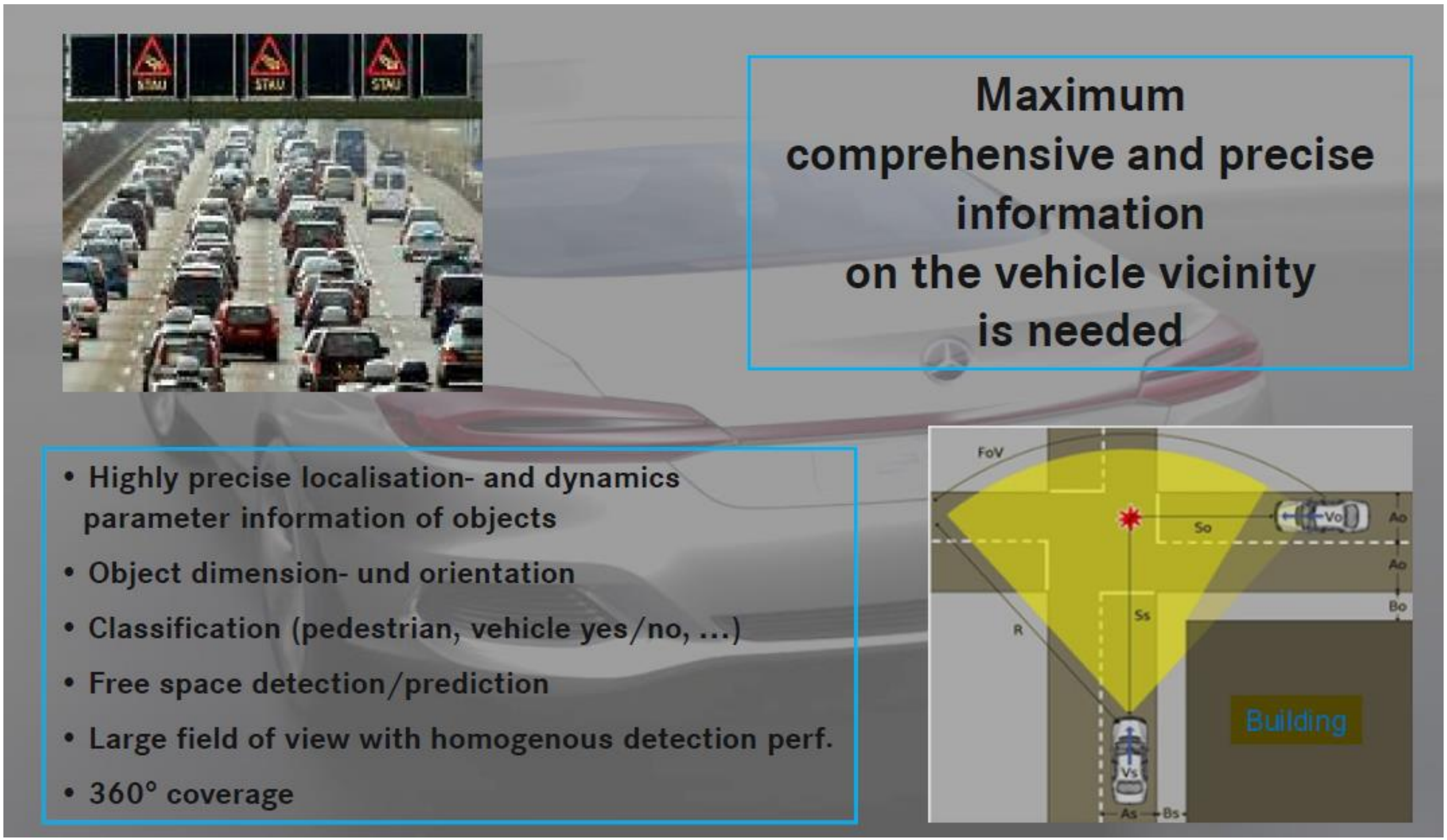
V2V communication





Visual and ranging sensing

Sensing Requirements for Autonomous Driving



From Daimler presentation IWPC2014 workshop

Sensing Technologies

2D

Camera

Dense, rich information
Color images
Low cost
Illumination sensitive

All vehicles

3D

Lidar

Stereo

Radar

Depth imaging

Ultrasonics

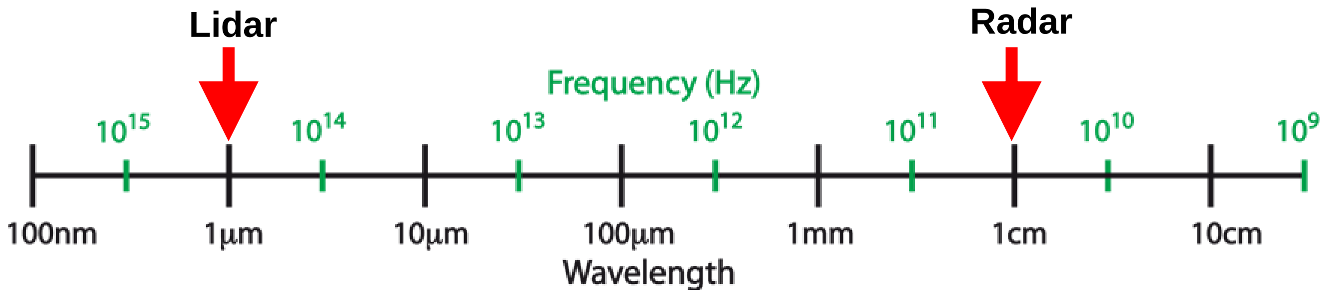
Direct range measurement
Improved functional safety

From Dr. Ran Gazit presentation, ATCI, GM

Radar vs. Lidar

$Resolution \sim \frac{\lambda}{D}$ — λ: Wavelength; D: Diameter of collector

$Scattering \sim \frac{1}{\lambda}$



Lidar:

Scattered by dust, heavy rain
Requires a "window"
Range limited by eye safety

Angular resolution 0.1° at D=2cm
Range resolution 1mm

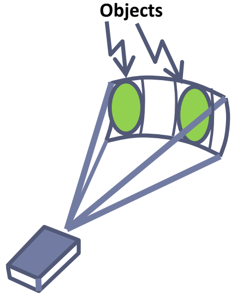
Radar:

All weather
Installation behind fascia
Large range
Direct velocity (Doppler)

Angular Resolution 1° at D=20cm
Range resolution 15cm

Radar vs. Lidar

Radar



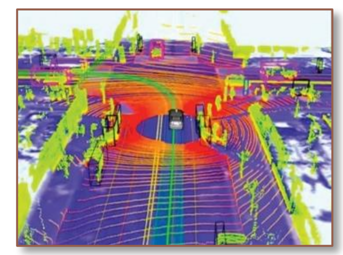
Affordable
Reliable
Sparse data

In production

Reduce cost

Increase resolution

Lidar



Expensive
Mechanical scanning
Dense data

Automated driving demos

From Dr. Ran Gazit presentation, ATCI, GM

History of Automotive Radars

1970

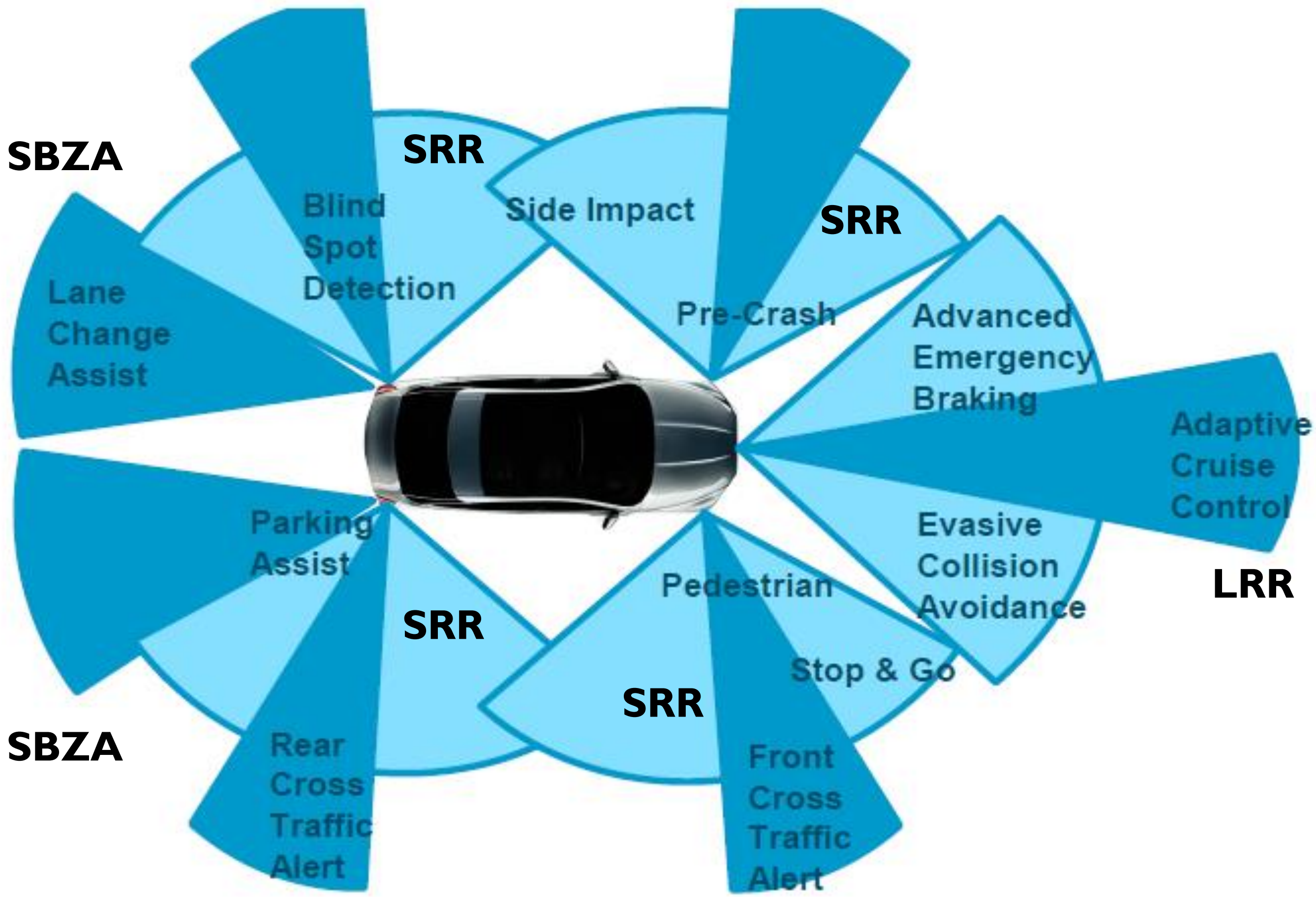
1974

1974

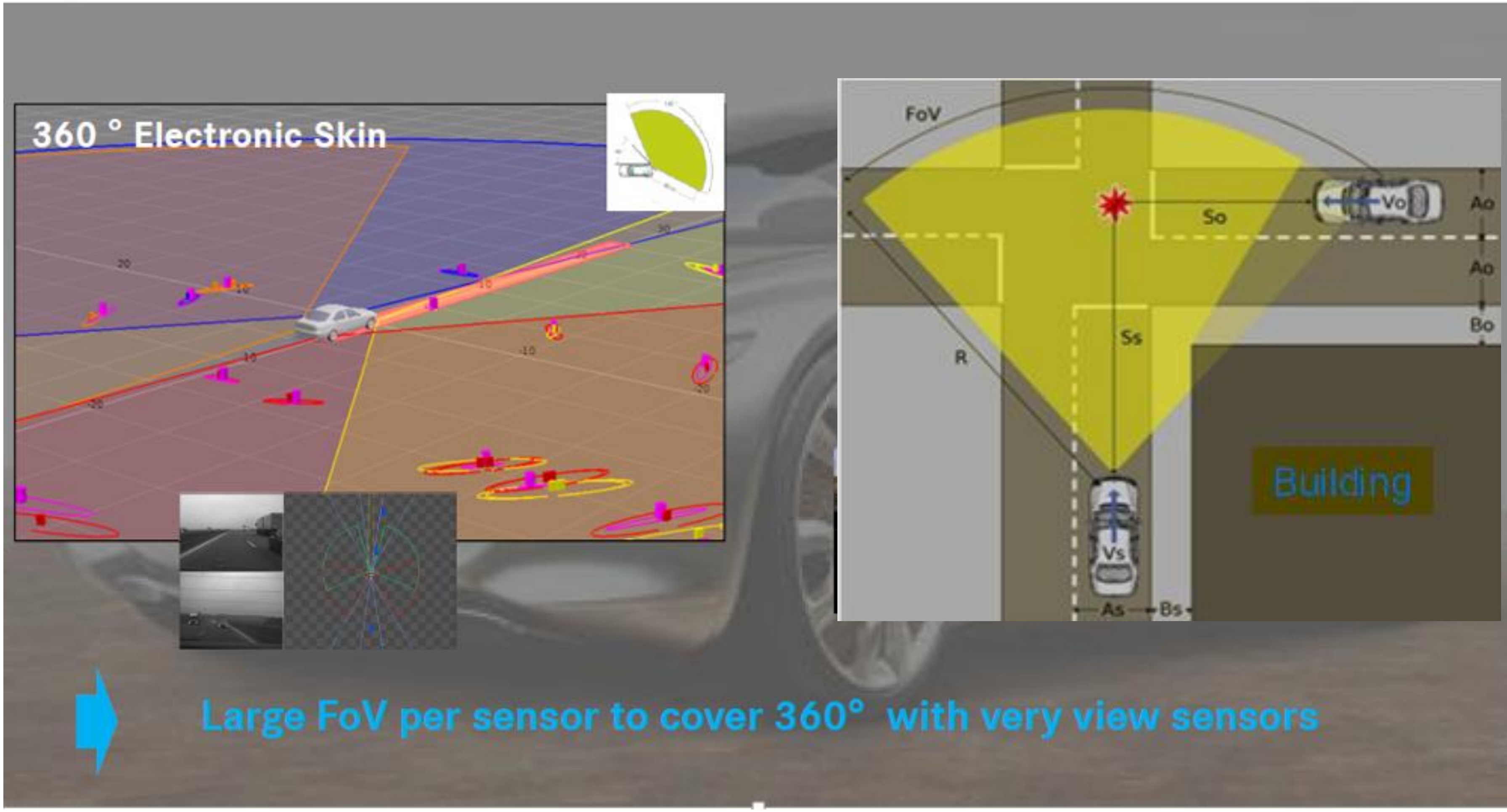
1980

From VW Presentation in IWPC Workshop, 2013

Radar Sensor Suit

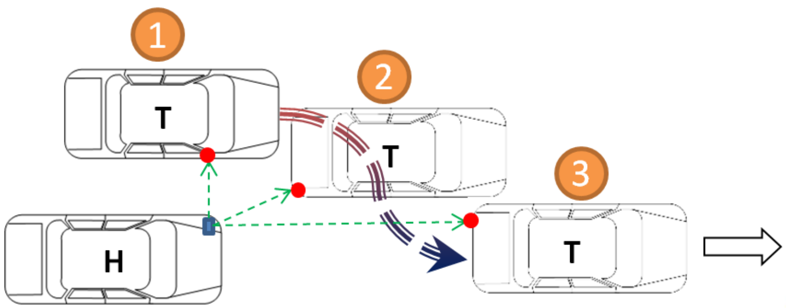


Large Field of View Requirement



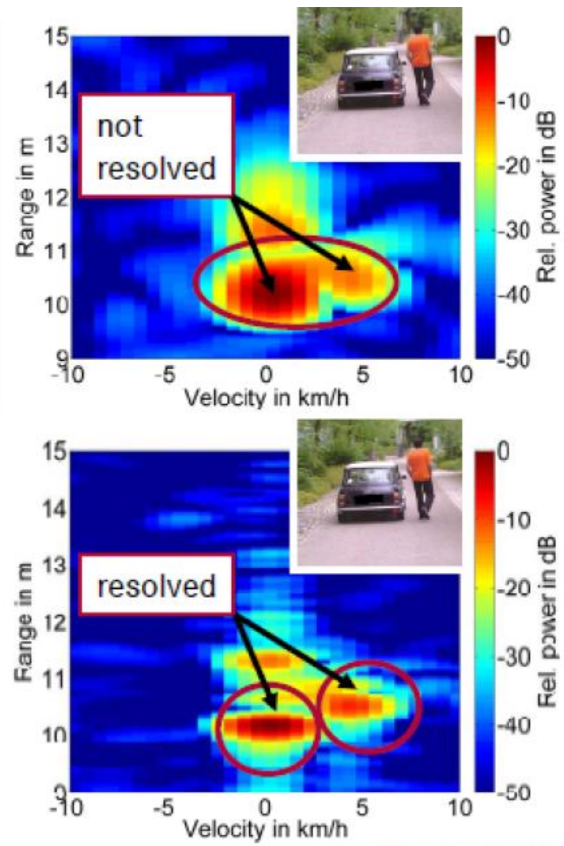
From Autolive Presentation in IET Radar Conference , Xi, 2013

Spatial Resolution Requirement



B_{net}: 0.5 GHz

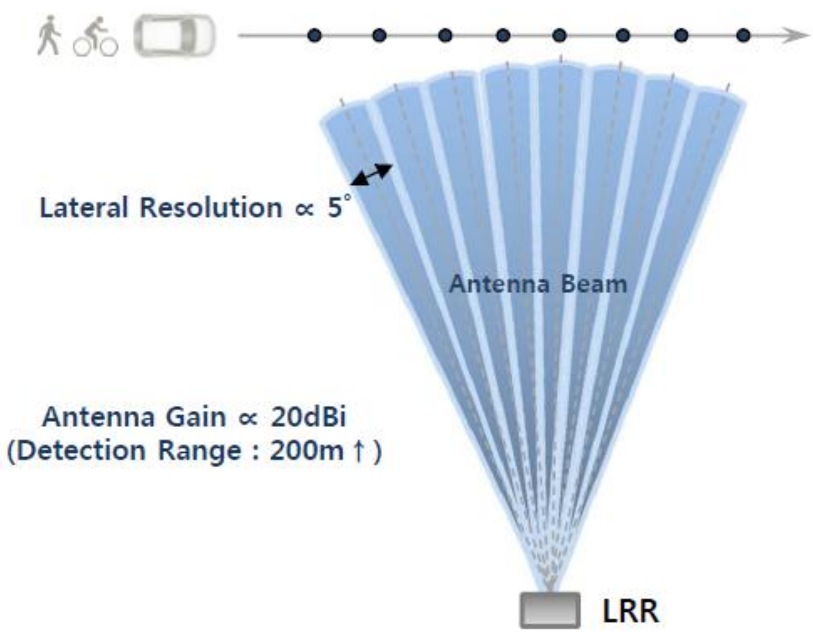
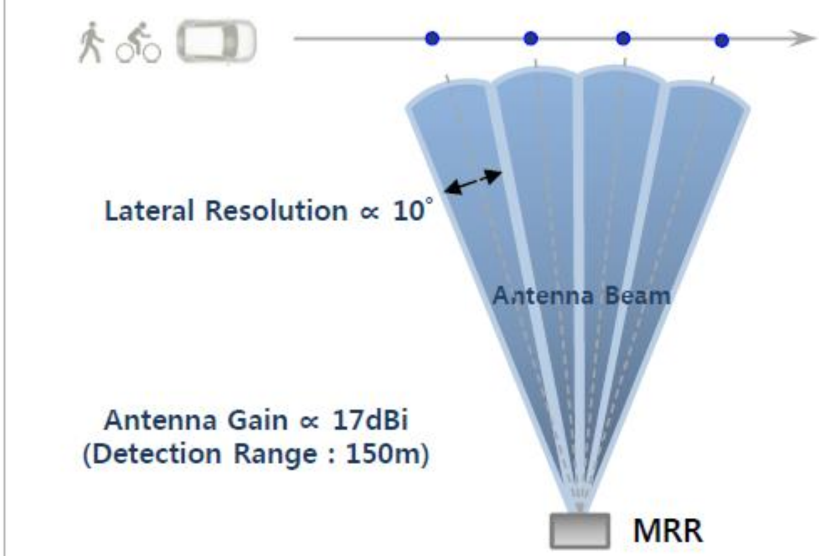
1.35 GHz



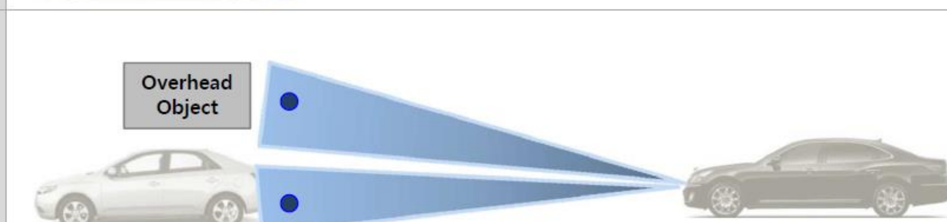
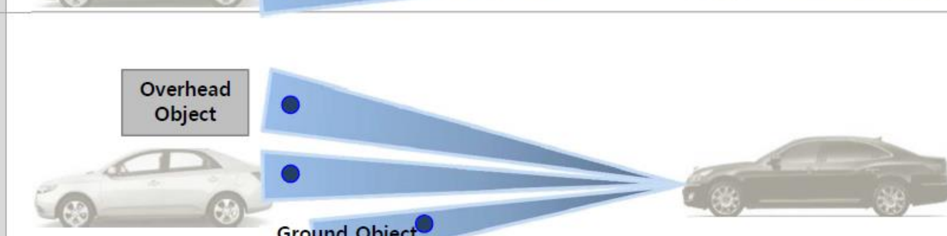
Source: Courtesy of DAIMLER AG

→Increased bandwidth resolves pedestrian and car.

Azimuth Resolution

Long Range Radar (LRR)	Mid Range Radar (MRR)
	
Rx 8 Channels ↑ , Antenna Size ↑	**Rx 4 Channels ↓ , Antenna Size ↓**

Elevation Resolution

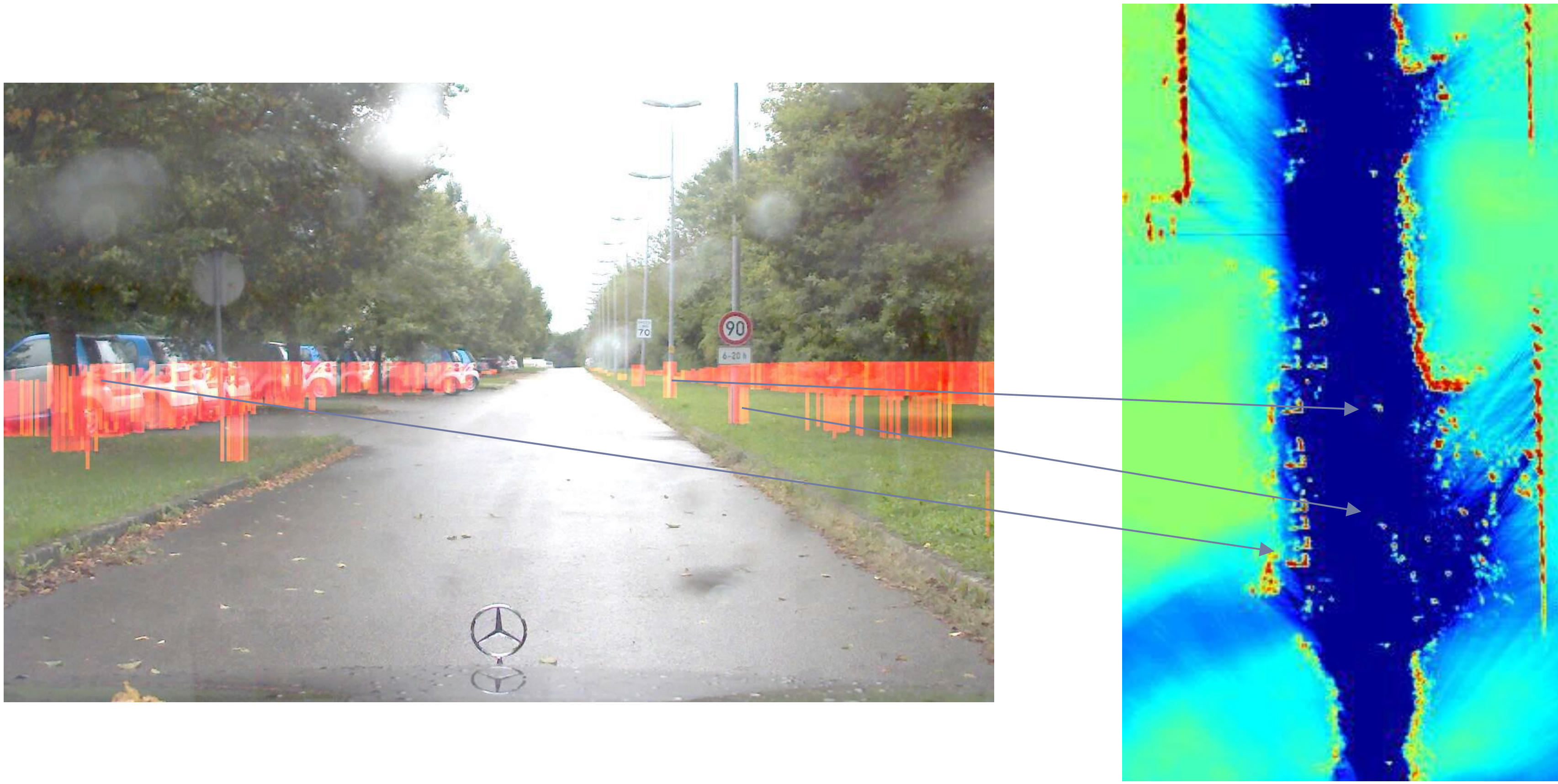
No of Tx Channels	Vertical Resolution	Comment
1Tx		Discrimination between Target and Overhead Object Impossible → Radar Only AEB X
2Tx		Discrimination between Target and Overhead Object Possible → Radar Only AEB O
3Tx		Discrimination among Target, Overhead Object and Ground Object Possible → Automated Driving O

From Daimler Presentation in IWPC Workshop, 2013

Radar Required Specification

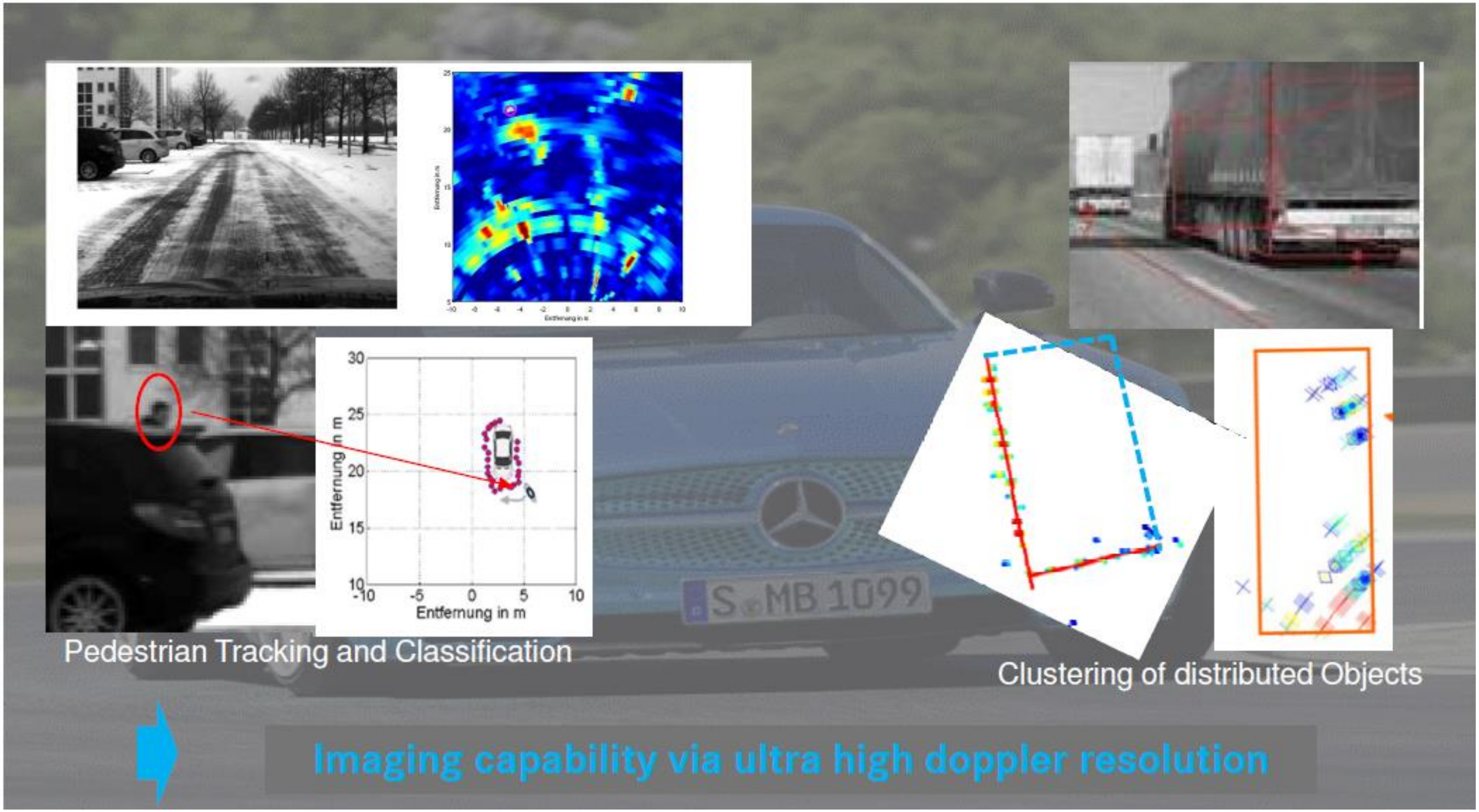
Key parameter	Value
Azimuth resolution **wide FOV (more than 140 deg)**	2 degree
Elevation resolution	3 degree
Dynamic range	Ability to distinguish multiple objects with RCS difference of 20 dB that are at the same range and Doppler frequencies but with differ in azimuth angle by more than 2 degrees.
Size	15cm in height and width
Cost	<100$

Imaging Capability



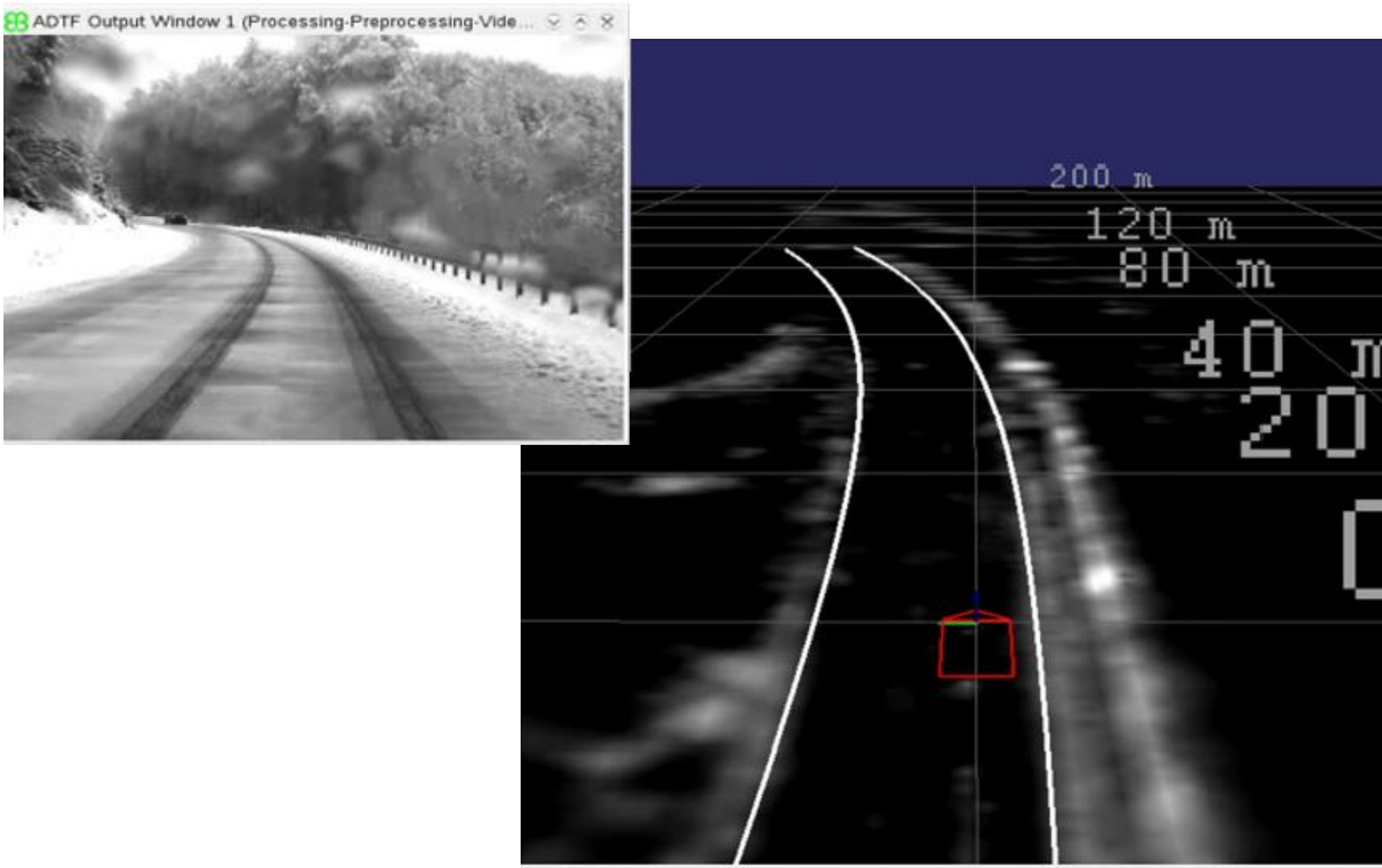
From: Markus Hahn and Jürgen Dickmann -- Autonomous Maneuvering with Radars, IWPC2015

Imaging Capability via Doppler Resolution



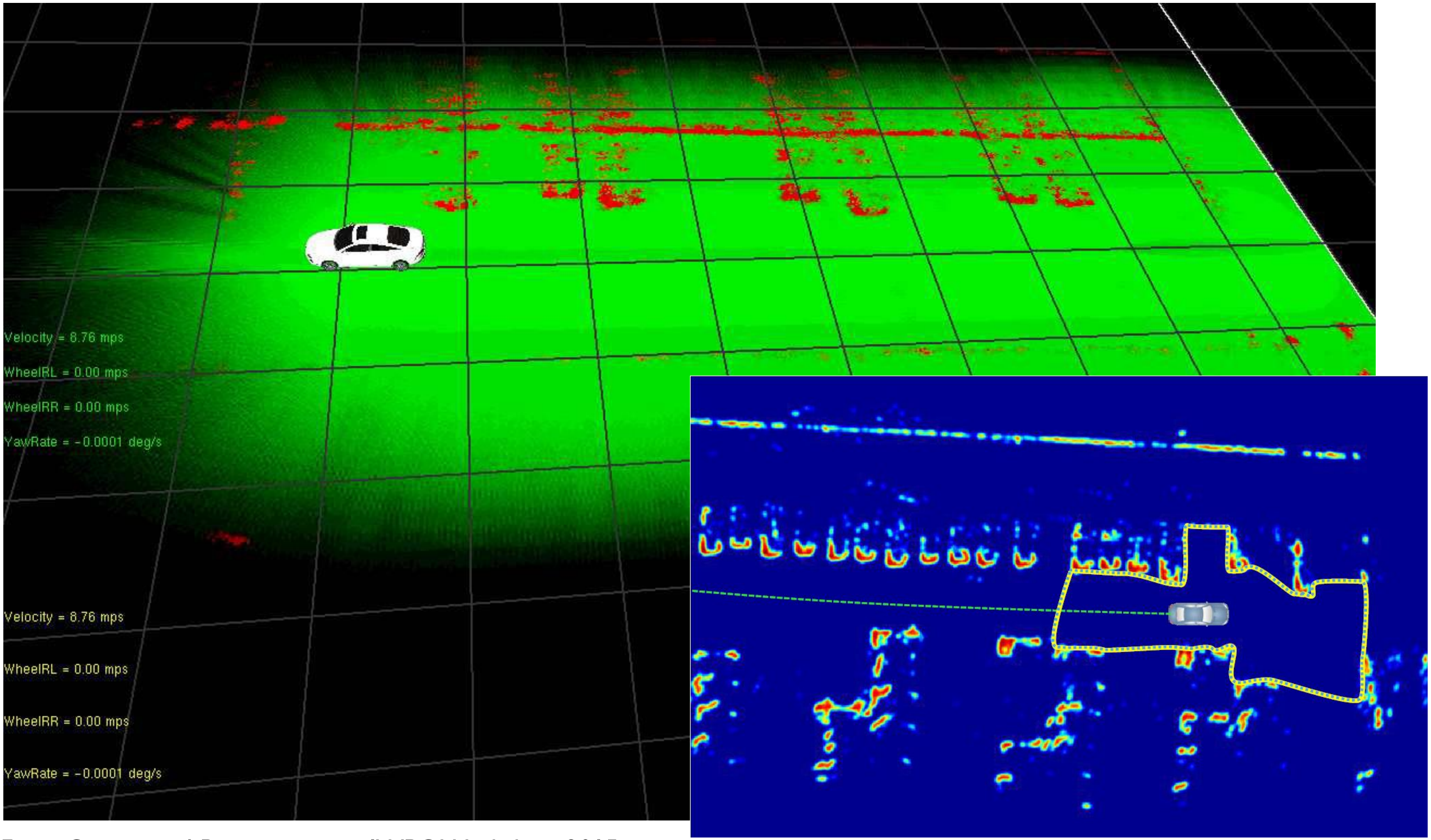
From Daimler Presentation in IWPC Workshop, 2013

Road Edge Estimation



From Daimler Presentation in IWPC Workshop, 2013

Parking spots detection



From Continental Presentation in IWPC Workshop, 2015

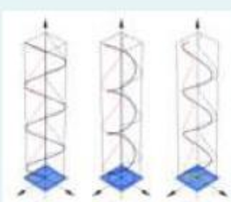
From Daimler Presentation in IWPC Workshop, 2015

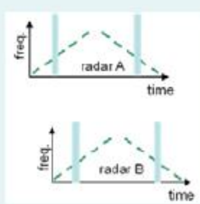
Radar Interference

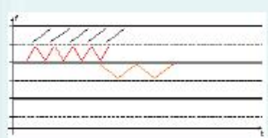
Interference Mitigation

MOSARIM project: Interference mitigation techniques

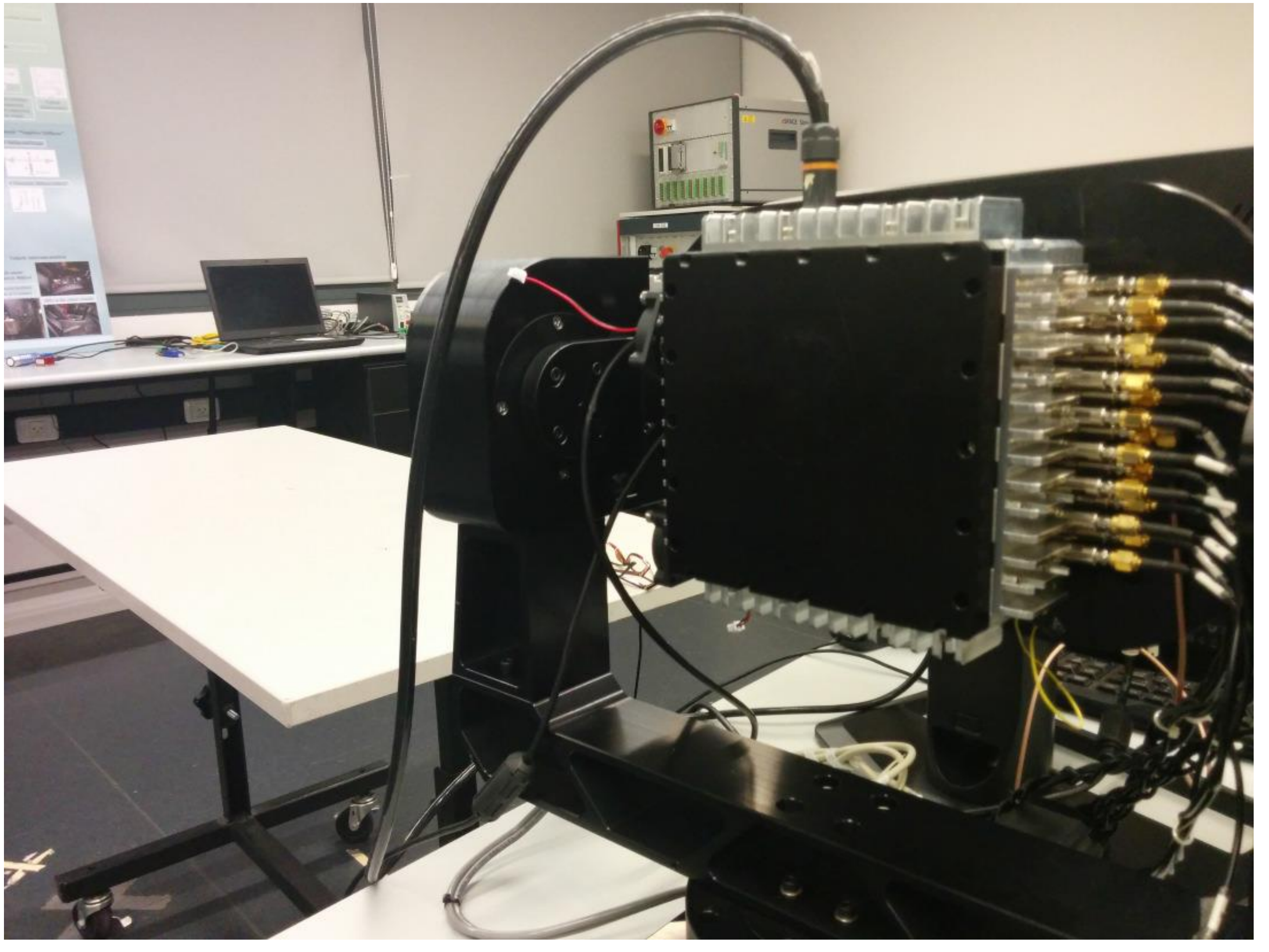
Polarization	Time	Frequency	Coding	Space	Strategic
key words	key words	key words	key words	key words	key words
- linear, circular, elliptical	- duty cycle (Tx)	- sub-frequency bands	- code length	- azimuth, elevation	- detection
- co/cross polarization	- receiver time	- random frequency hopping	- reception ordering	- FOV, range	- avoid, omit, repair
	- random time		- orthogonality	- scanning	- communicate







GM Radar Prototype



Conclusion

- Automotive driving turning to be reality and requires higher performance sensors
- Sensor fusion can nor resolve all problems and better sensors are required
- There is a clear requirement to adopt more advanced radar approaches into automotive applications
- Novel signal processing algorithms are required to exploit all possible information from the radar measurements
- Automotive environment poses novel challenges that require new algorithms and radar approaches

We are Hiring

- Signal Processing Algorithms Developers
- DSP Embedded engineers
- Radar testing Engineers
- Radar system Integration engineers
- Contact: Igal.Bilik@gm.com