Improving Autonomous Vehicle signal response with Functional Pigments

Contributors:
Dr. Paul Brown
Dr. Thomas Frey
Michael Jakobi
Mike Crosby

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The Evolution towards Autonomy is underway

Today
(Level 0 Hands on → 2 ADAS Hands off)

…to here (Level 3 & 4 Eyes off)

….or even here (Level 5 Mind off)

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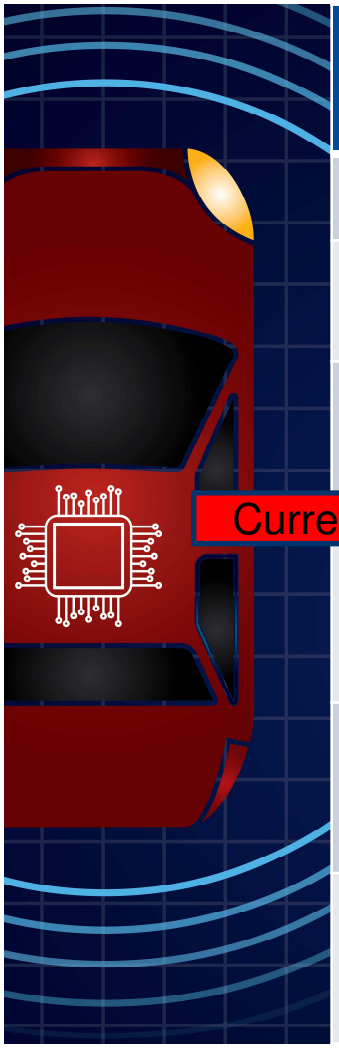
Sensory systems are enablers for Higher Levels of Autonomy



Autonomy Level	Capability / Technology	Sensing / Software
0 – Manual	Driver controls all aspects.	Park sensors, back up camera
1 – Single Automated aspect	Cruise control, Lane keep, or Emergency braking	Multiple cameras, cross traffic short range radar
2 – Mode dependent ADAS	Park Mode; Lane Keep Steering, Adaptive cruise control pacing (ADAS)	Stereo cameras, **Mid & Long range Radar**
3 – Limited, conditional automation	Highway driving with speed and lane navigation monitored by driver.	**Lidar environmental mapping** & Object identification software
4 – Autonomous, human overtake possible	Automated personal commutes, Robo taxi service.	Advanced decision algorithms for most environments. Potential for thermal imaging.
5 – Adaptive autonomy. No human controls.	Off-road capable, intelligent vehicles designed to operate without human intervention.	Advanced mapping & artificial intelligence.

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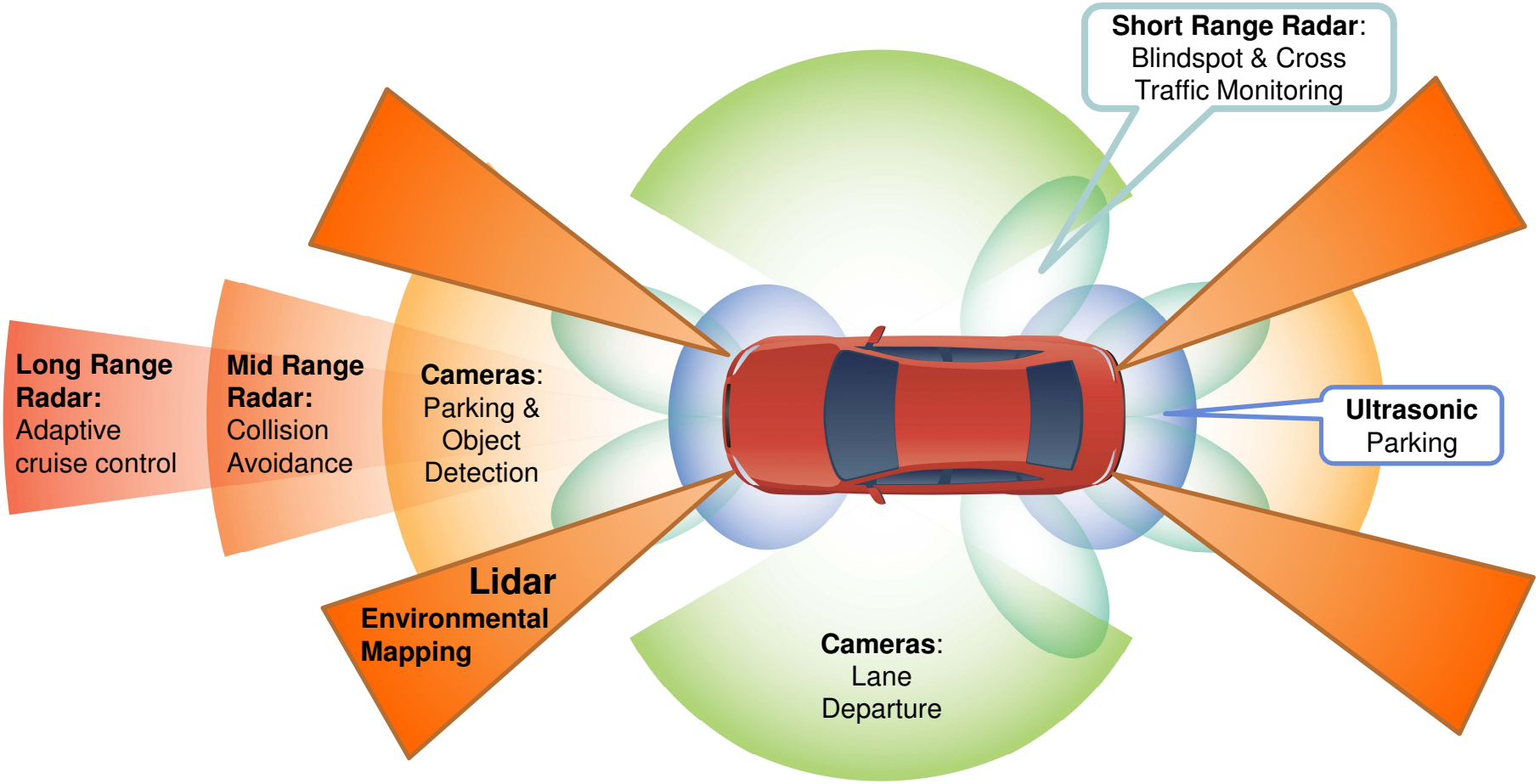
Future Sensory Arrays for Autonomous Vehicles



- Most OEMs view Lidar as a Level 3 prerequisite and adoption is accelerating given improved range, capability and cost profile.
- ***Pigment selection can influence signal transmission from vehicles and signal reflection from objects in the surrounding environment.***

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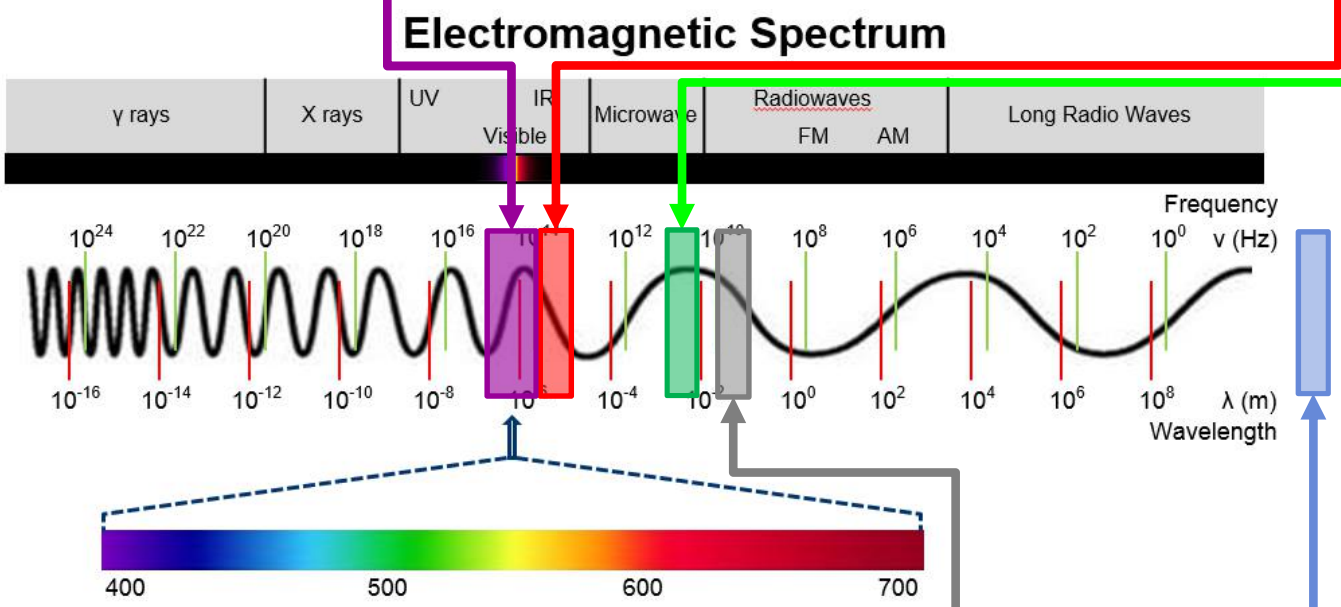
Pigment considerations for the AV Sensor Spectrum

Visible 400-700nm (750-430THz)
Human and machine visibility through conventional video cameras operating in the visible spectrum
Required for all levels of autonomy
Totally dependent on pigment choice

Lidar 885, 905 & 1550nm (330 & 0.2 THz) Near Infra Red
+ Long range precise environmental mapping & object tracking
100m ADAS Level 2, 250m likely required for Level 3 Autonomy
Significant influence by pigment choice. Traditional carbon black PBk7 strongly absorbs NIR so functional blacks are recommended.



Radar Long & Short Range
+ Larger object location & movement tracking in poor lighting or weather conditions. LR: Adaptive Cruise Control & Emergency Braking (150-250 m)
SR: Blind spot & Cross traffic detection (5 – 100m)
Microwave 4 & 12mm (77GHz & 24GHz)
Strong impact from substrate material & thickness as well as metallic pigment use.

Ultrasonic
Close proximity parking assist
Minimal pigment impact.

(GPS) Global Positioning
Vehicle Position & Navigation
Microwave 19 & 24cm (1575MHz &1228MHz)
Minor pigment impact

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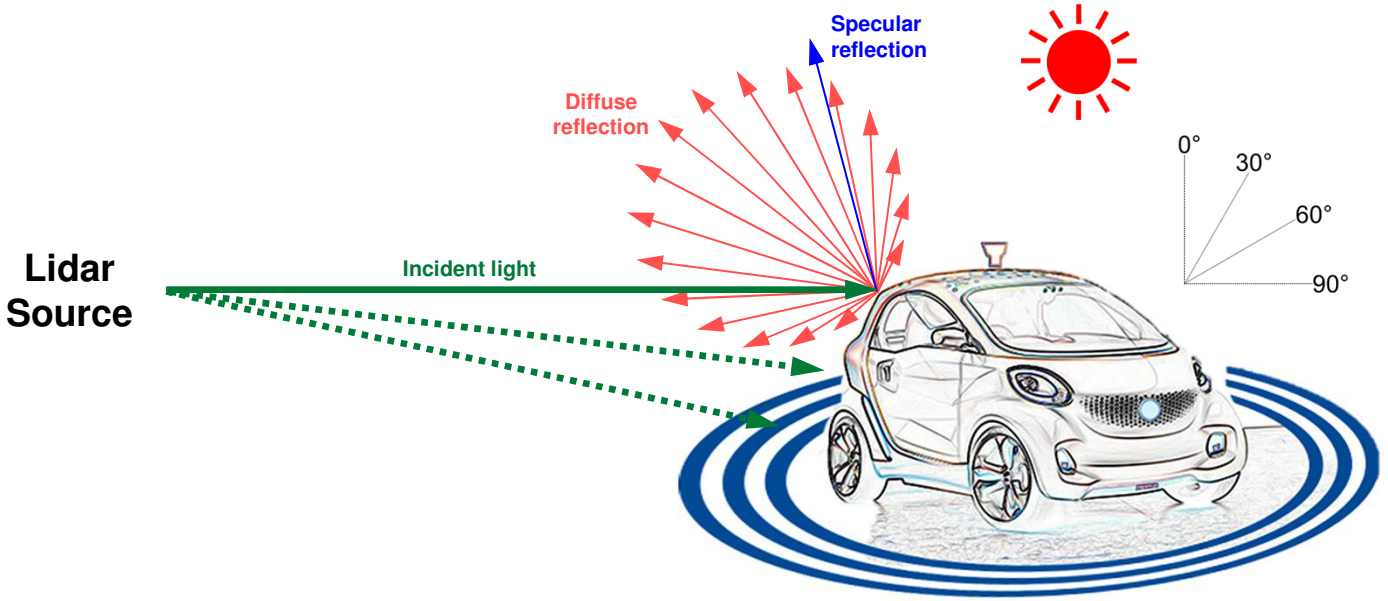
Lidar Specular & Diffuse Reflection Considerations

- Traditional Lidar system point cloud density decreases with distance. At 150 -200 meters away perhaps only a few Lidar beams will hit surfaces of an oncoming vehicle.
- Car surfaces are not flat so the points at which Lidar beams hit an object are rarely oriented at a perfect face angle. Therefore both diffuse and specular reflections are important.
- Reflections from distant points on a target need to have sufficient return signal strength to enable the Lidar system to differentiate object presence from ambient NIR noise.



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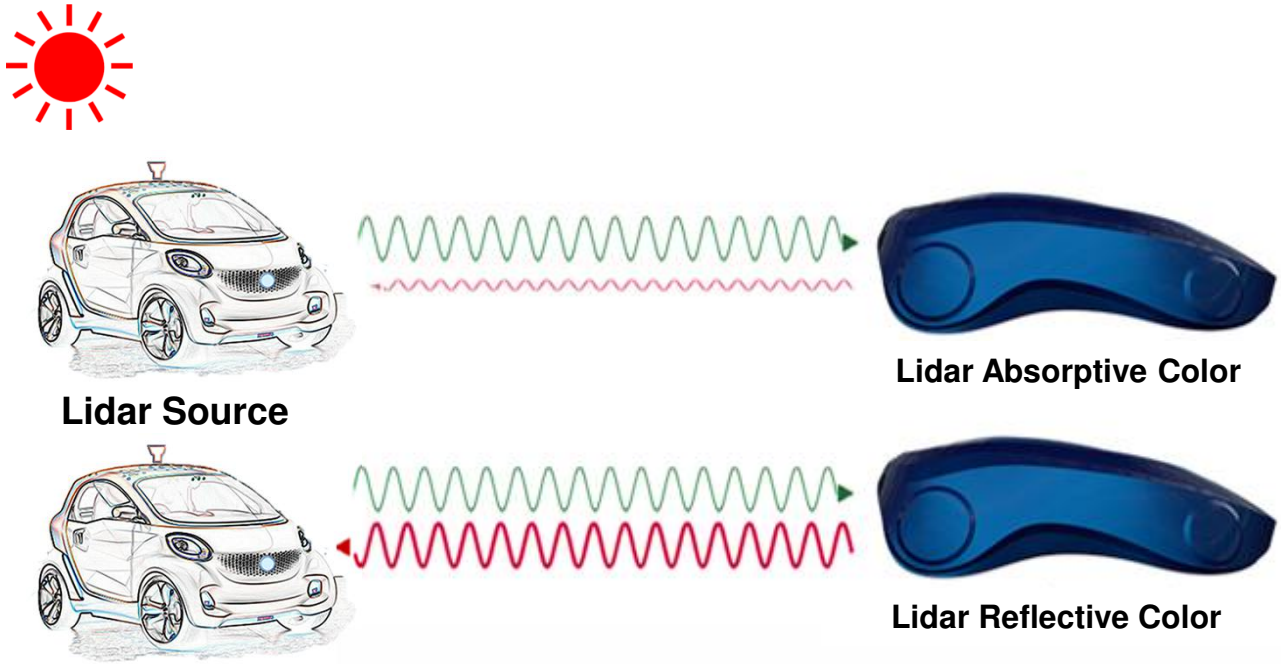
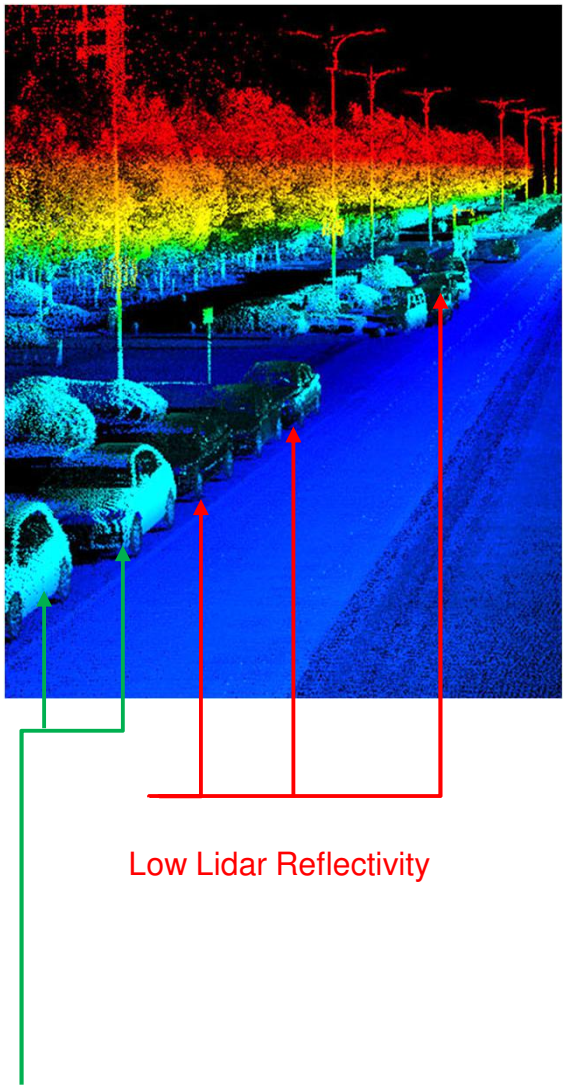
Low reflectivity objects are harder to discern or ‘see’

Objects with a low reflectivity compete with ambient noise so are not readily detected or classified by Lidar systems.





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The black & dark color detection problem

A simple demonstration of a Lidar controlled robotic vacuum attempting navigation around two black colored panels highlights the low signal reflection challenge of dark colors.

Insufficient Lidar return signal from a panel coated with conventional black pigment resulted in a collision.

Stronger Lidar return signal from a panel coated with functional black pigment over reflective primer was sufficient for object detection and avoidance.

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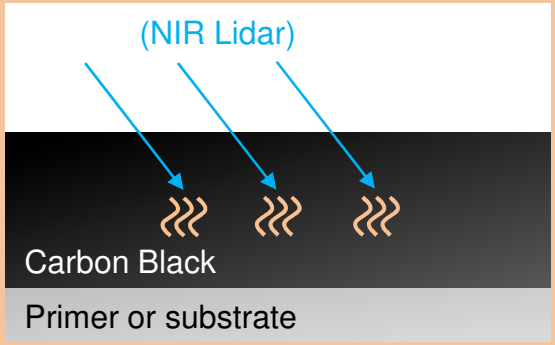
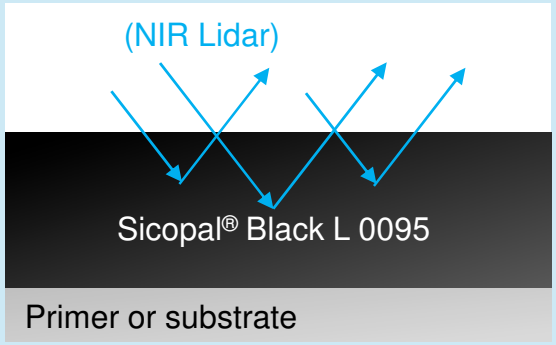
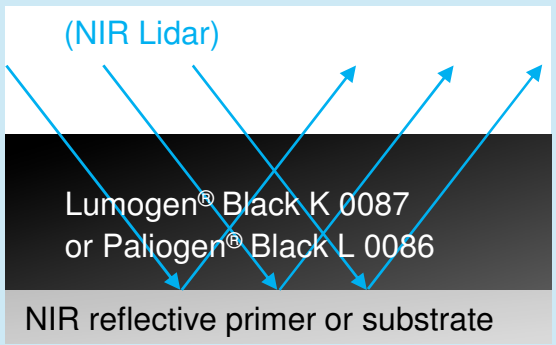
Two Solutions for dark object low signal return

The Challenge	Two Solution Approaches	
Absorptive Pigmentation	**Reflective Pigmentation**	**Transparent Pigmentation**
		
Signal is primarily ***absorbed*** by the carbon black pigmented layer.	Signal is primarily ***reflected*** by the NIR reflective pigment in the black layer.	Signal is primarily ***transmitted*** through the black layer and then reflected by a primer or substrate.
Coating does not return adequate signal to detector	**Coating returns sufficient signal to the detector**	**Coating returns sufficient signal to the detector**

** Absorption, Reflection, and Transmission are relative not absolute terms*

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Functional Black Pigments
Transparent & Reflective options from our range

Typical Applications	Product Names	Classification	Chemistry / CI Number	*NIR Behaviour
Coatings & Plastics	**Paliogen® Black L 0086**	Organic	Perylene / PBk 32	Transparent (>780nm)
Coatings & Plastics	**Lumogen® Black K 0087**	Organic	Perylene / PBk --	Transparent (>850nm)
Coatings & Plastics	**Lumogen® Black K 0088**	Organic	Perylene / PBk --	Transparent (>1050nm)
Coatings & Plastics	**Sicopal® Black L 0095**	Inorganic	Inorganic Fe/Cr MMO / PBr29	Reflective (>1120nm)
Inks & Printing	**Paliogen® Black S 0084**	Organic	Perylene / PBk 31	Transparent (>730nm)
Electronic Specialties	**Irgaphor® Black S 0100CF**	Organic	Lactone / PBk --	Transparent (>780nm)

Coatings pigment grades are suitable for automotive and aerospace applications

* NIR behaviour classified as achieving ≥ 70% reflectance for the mass tone pigment (20% PWC / 20µm) over a Leneta white substrate

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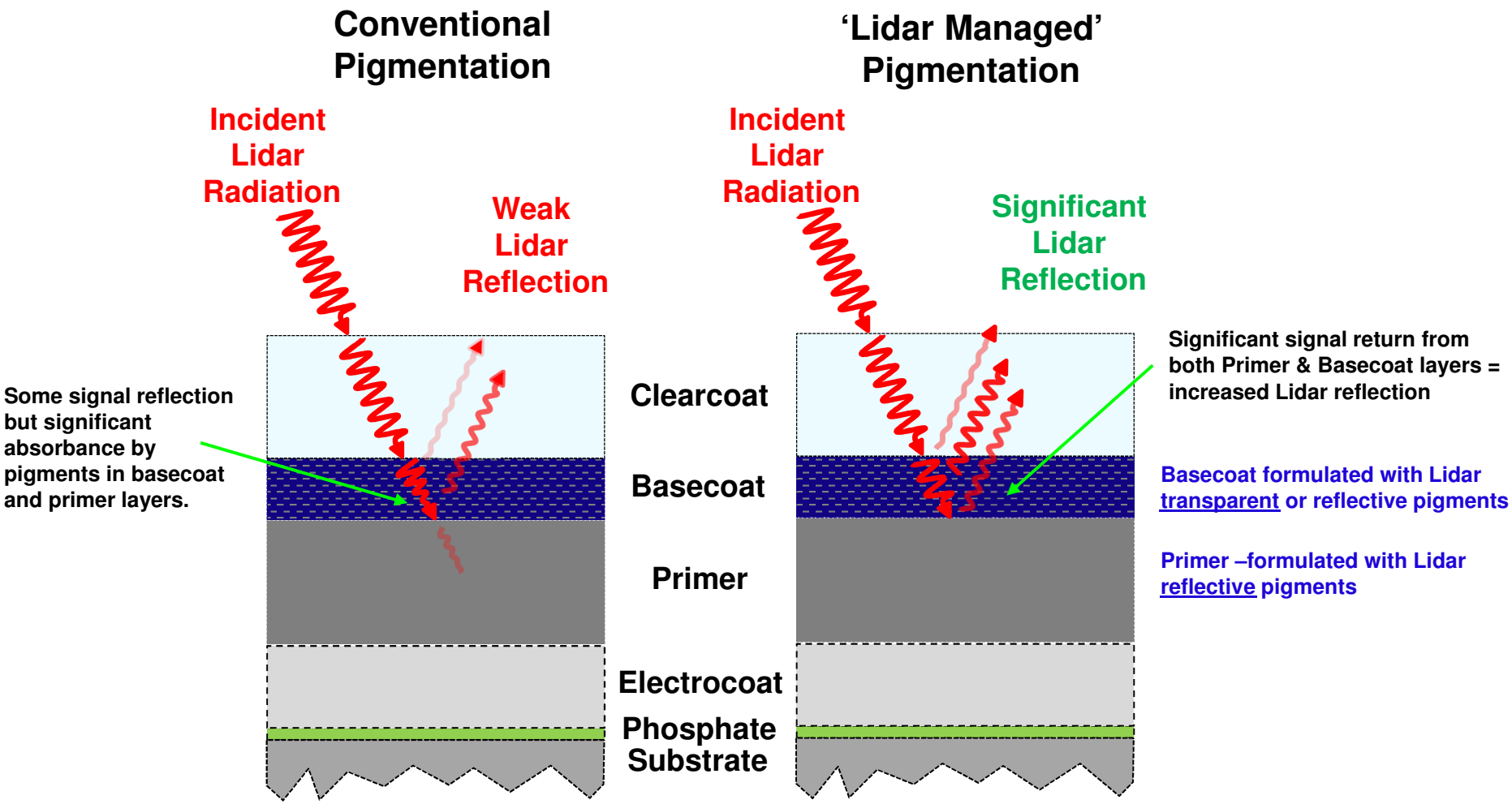
Lidar Functional Coating Stack Design

A ‘Conventional’ automotive coating stack pigmentation approach



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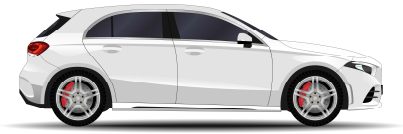
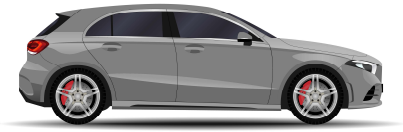
Lidar Functional Pigment Selection

- **Using functional black pigments to replace carbon black in basecoats significantly improves a color's Lidar response.**



- **Lidar visible coatings are achievable in most color spaces through appropriate pigment selection early in the design cycle.**



- The optimal choice of pigments depends on a variety of factors:
  - Color, lightness, and desired effect of the targeted styling
  - The Lidar response of other colored and effect pigments with the basecoat
  - Coating layer stack construction
  - Lidar reflectivity behavior of the primer or substrate

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How can BASF Colors & Effects support?

- **Technical support services including:**
  - Color match assistance for existing and concept colors
  - Optimal functional pigment selection based on substrate, coating stack, and color
  - Predictive Lidar response modeling based on potential pigment formulations
  - Angle-dependent Lidar reflection measurement capability by end of 2019

- **Industry leading Lidar functional black pigments** including transparent and reflective black pigments.

- **Broadest range of pigments** with known Lidar characteristics including:
  - Highest chroma organic pigments (which are largely transparent)
  - Numerous inorganic chemistries (transparency varies depending on chemistry)
  - Iron oxide and interference pearlescent pigments based on synthetic or natural mica flakes, sourced at our wholly owned mine in Hartwell, USA
  - Iron oxide coated aluminum effect pigments

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For more information or support, please contact us…

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Americas

BASF Colors & Effects USA LLC
24710 West Eleven Mile Road
Southfield, MI 48034 USA

Andre.Bendo@basf.com
Mike.Crosby@basf.com

EMEA

BASF Colors & Effects GmbH
An der Rheinschanze 1
67059 Ludwigshafen Germany

Michael.Jakobi@basf.com
Paul.Brown@basf.com

Asia Pacific

BASF Colors & Effects Shanghai Ltd.
No 300, Jiang Xin Sha Road
200137 Shanghai China

Helen.Deng@basf.com
Beilei.Li@basf.com