



# Measuring What the Customer Values: Automotive Paint Quality Metrics

**Linda Gerhardt, PhD**

**Paint Quality & Competitive Benchmarking**

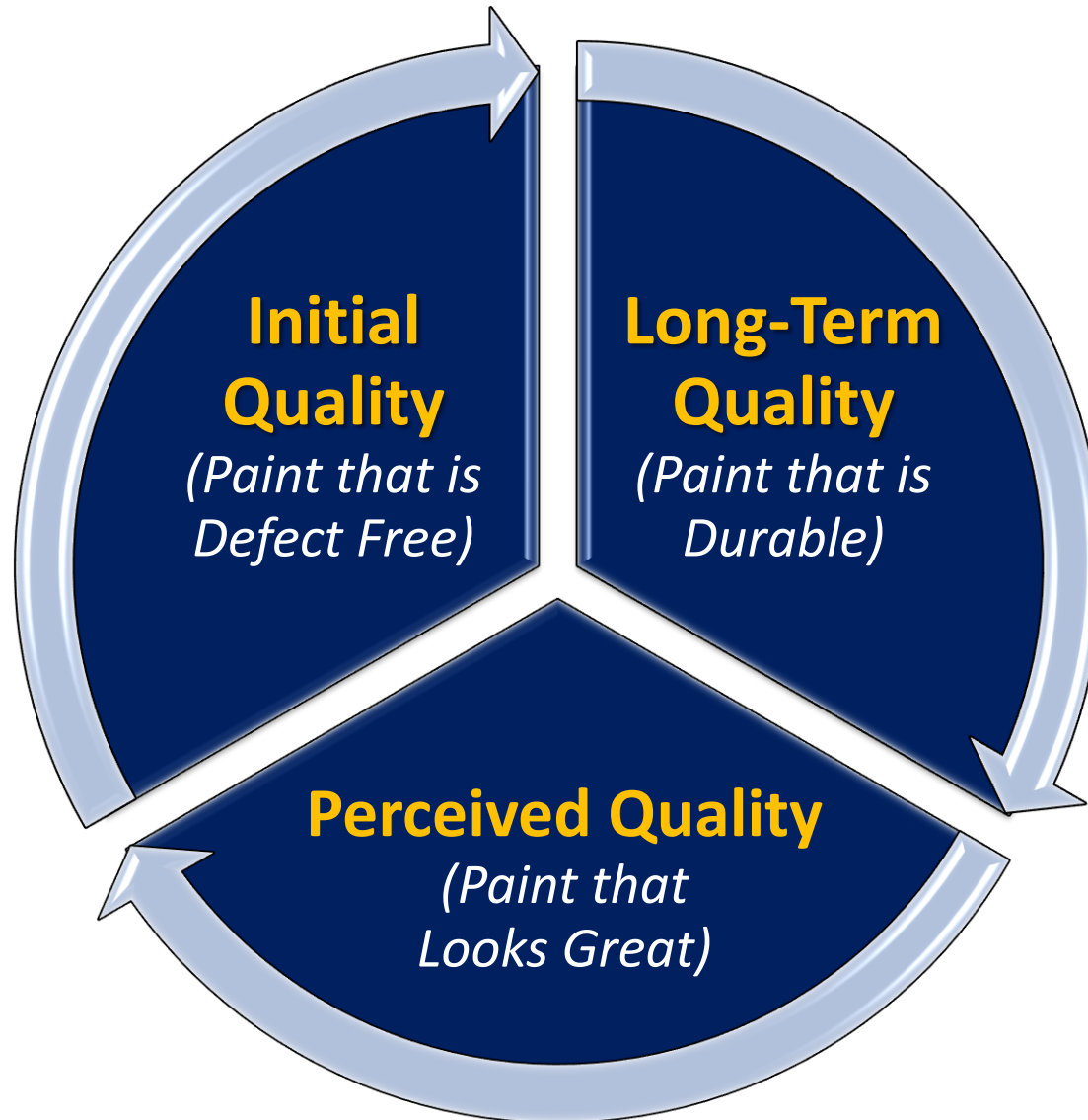
**Global Center - Strategy and Planning**

**GM ME Vehicle Systems**

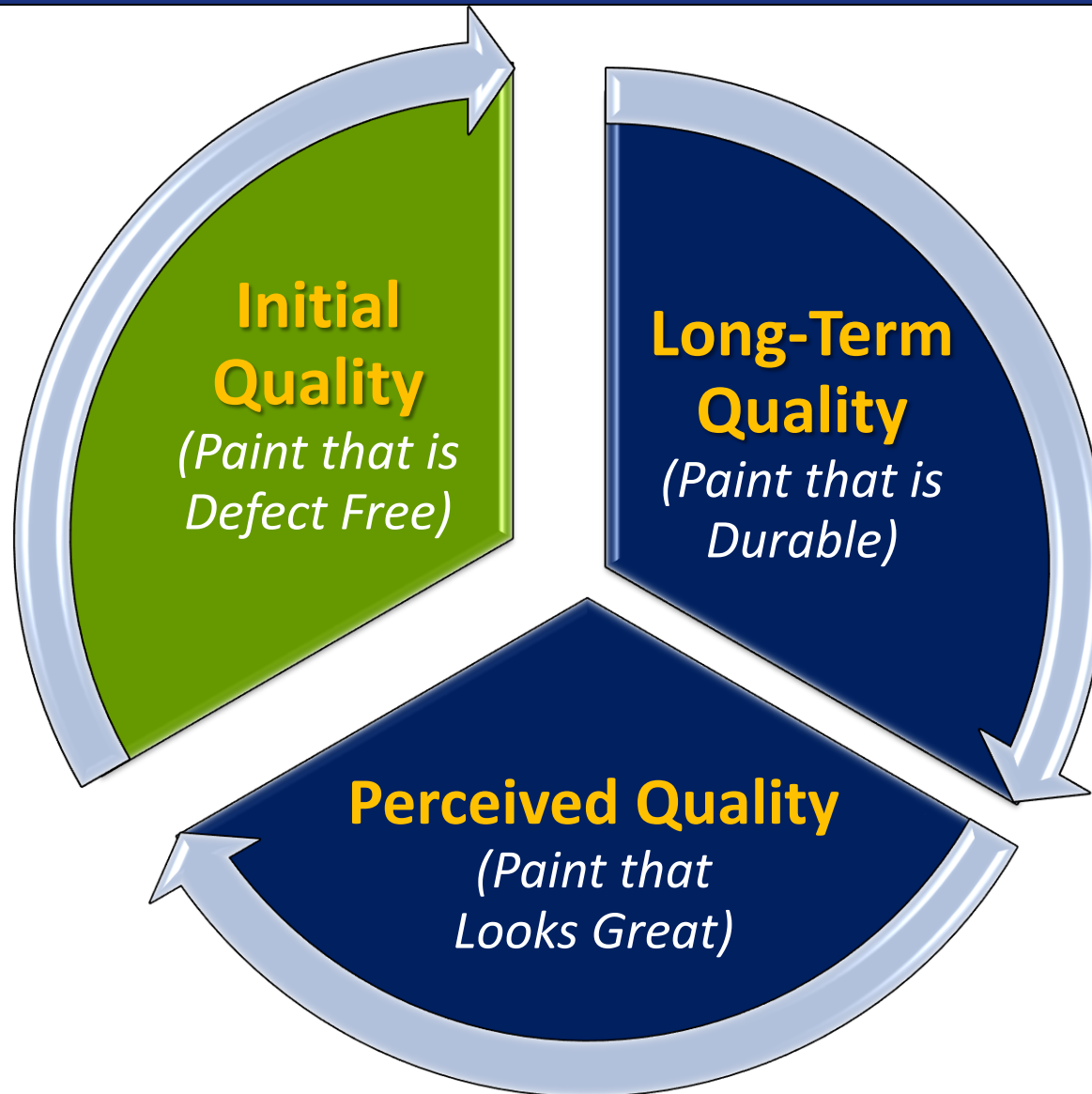
**2<sup>nd</sup> BYK-Gardner Iberian Automotive Meeting, Alicante, October 2014**



# Paint Quality: Areas of Focus



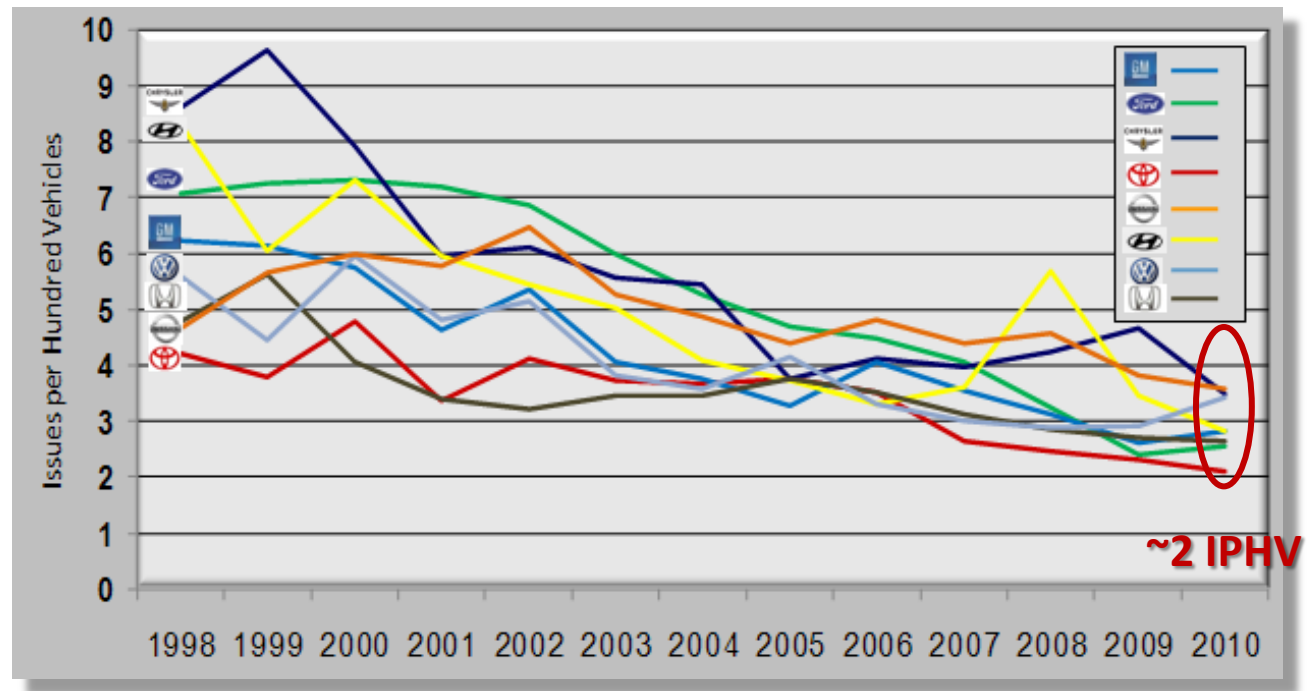
# Paint Quality: Areas of Focus



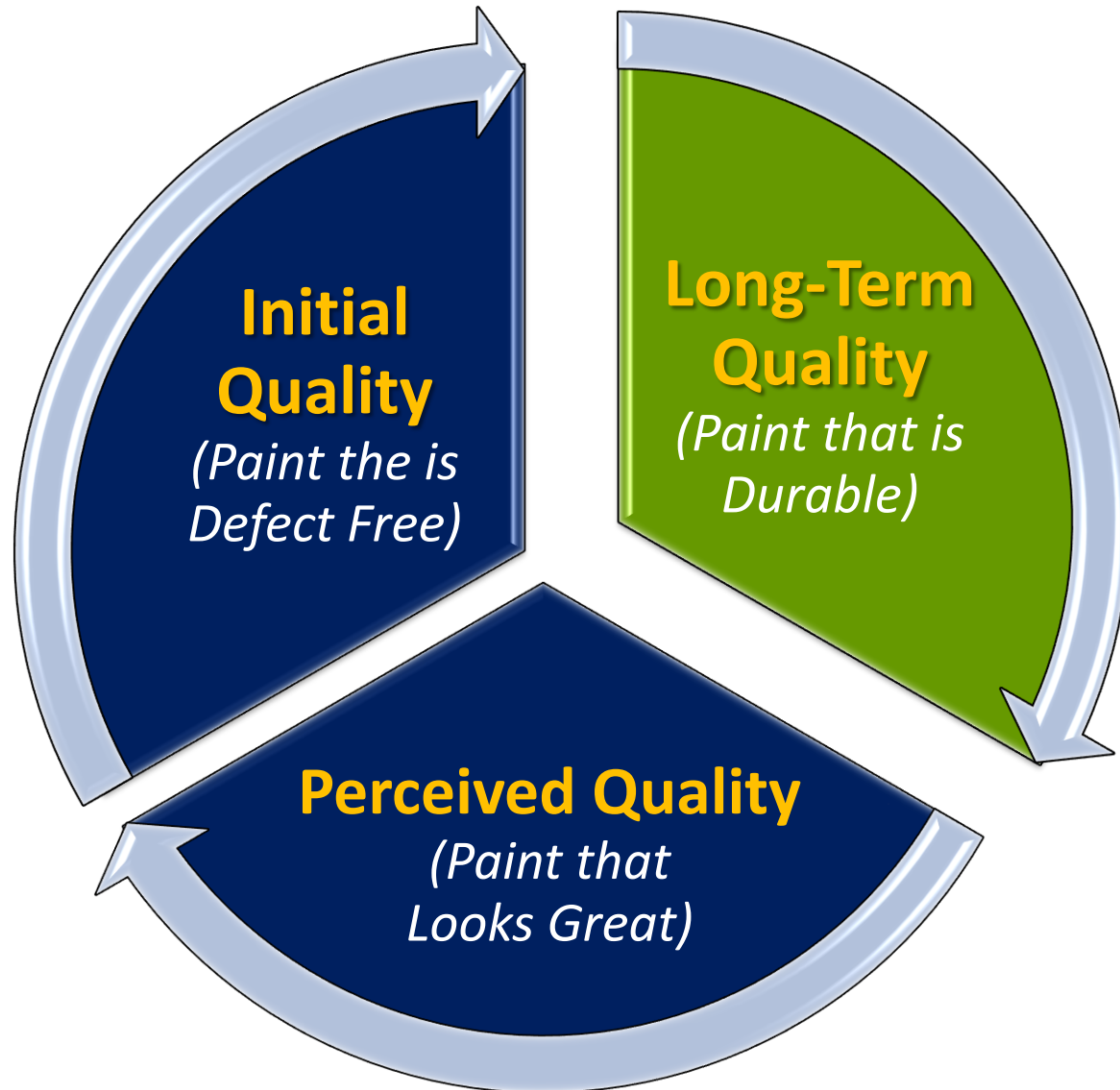
# Initial Quality: JD Power IQS3

- ◆ Initial Quality is Statistically Clustered
- ◆ JD Power IQS3 - First 90 Days of Ownership
- ◆ Paint Defects

- Blemishes
- Dirt
- Runs
- Peeling
- Chips
- Scratches



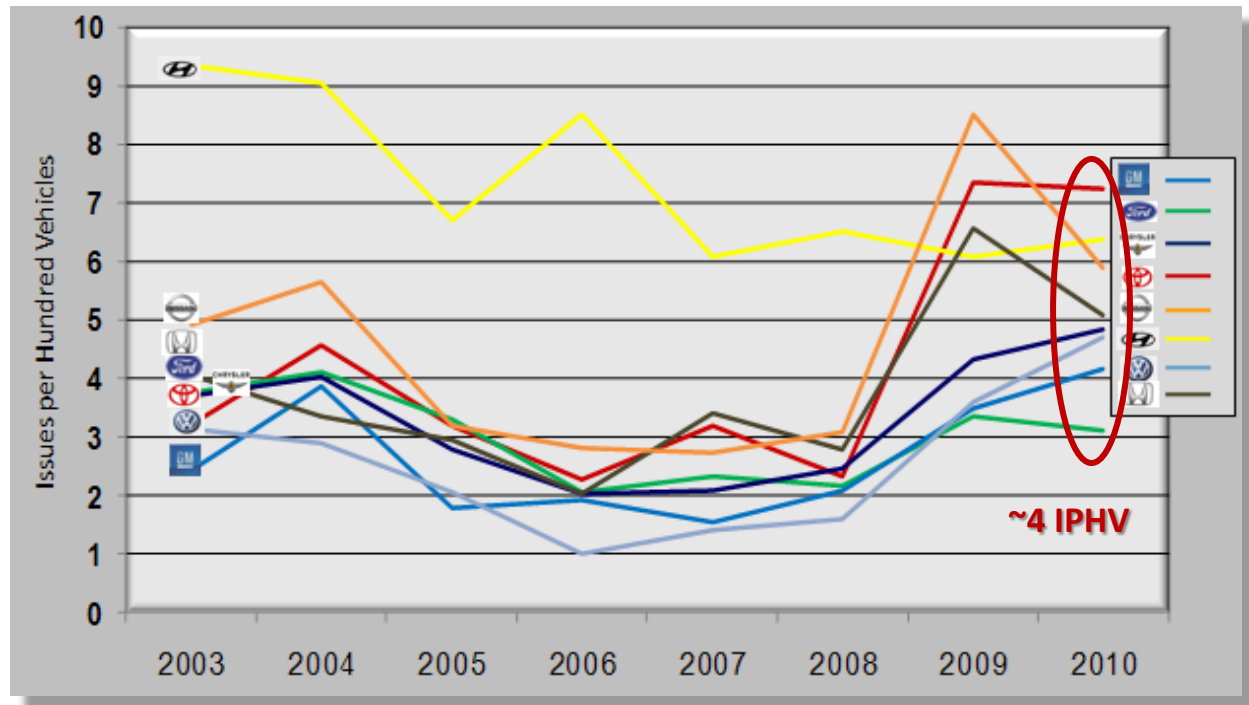
# Paint Quality: Areas of Focus



# Long-Term Quality: JD Power VDS

- ◆ Long-Term Quality is Statistically Clustered
- ◆ JD Power VDS - Measured at 3 Years
- ◆ Paint Durability

- Fading
- Chipping
- Peeling
- Cracking



# Paint Quality: Areas of Focus



# Perceived Quality: Defined

- ◆ An Emotional Reaction
- ◆ Not Easily Explained or Defined by the Customer
- ◆ Direct Link to Financial Performance
- ◆ Perceptions Often Hold After Actual Quality has Changed
- ◆ Reputation and Past Quality Performance are Key Factors Impacting Current PQ



*“... Perceived Quality is the Single Most Important Contributor to a Company’s ROI, having more Impact than Market Share, R&D, or Marketing Expenditures...”*

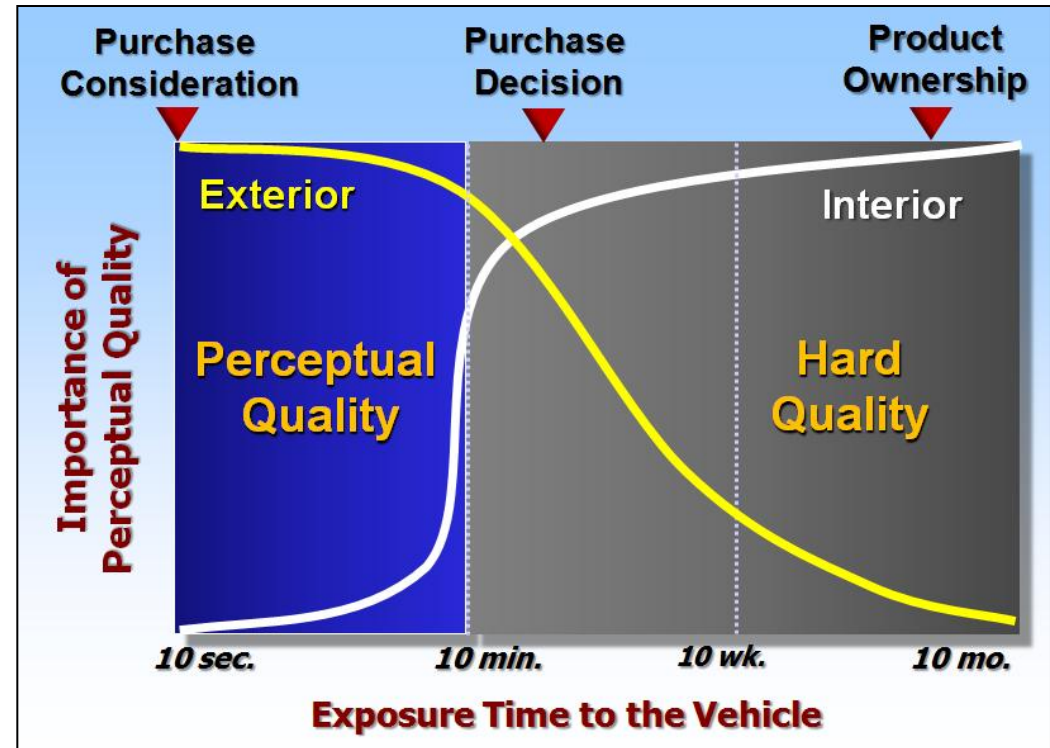
*Aaker, Dr. David, Building Strong Brands,  
New York: Simon and Schuster, Ltd., 2002*





# PQ: Exterior Appearance Contribution

- ◆ Initial Perception of Quality Occurs during the first 10 minutes
- ◆ First Impressions Extend Beyond Exterior Appearance
- ◆ Impressions are Not Easily Captured in Standard Quality Metrics



GMU Quality College, Course 20783

# Paint Perceived Quality: A Science

- ◆ Engineering Methodologies have been applied to Capture the Customer's Emotional Reaction
- ◆ PQ Dimensions have been Derived from Product Reviews and Customer Clinics / Verbatims
- ◆ Objective Metrics have been Correlated with what the Customer Sees and Values
- ◆ Benchmarking and Data Collection Allow Real BIS Target Setting, as Competitive Data are Analyzed

***“You Can't Manage What You Don't Measure.”***

-- Peter Drucker



# A True Global Snapshot!



**55 Brands**  
**>350 Models**

**All Regions**  
**15 Countries**



# Field Survey - Validated Instruments



## Exterior Surface Appearance

- Nominal Orange Peel “R” Value & Surface Uniformity
- Shortwave (SW), Longwave (LW), DOI
- Structure Spectrum (du-We) & Structure Balance (B)



## Color Harmony

- Fascia and Body to Standard
- Fascia to Body Harmony
- Supplement to Visual Harmony Reviews



## Metallic Mottle

- Nominal Mottle “M” Value
- Mottle Spectrum

# Objective Instrumental Measurement



## Exterior Surface Appearance

- Nominal Orange Peel “R” Value & Surface Uniformity
- Shortwave (SW), Longwave (LW), DOI
- Structure Spectrum (du-We) & Structure Balance (B)



## Color Harmony

- Fascia and Body to Standard
- Fascia to Body Harmony
- Supplement to Visual Harmony Reviews

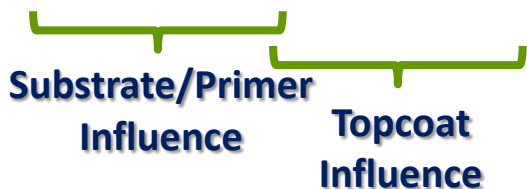
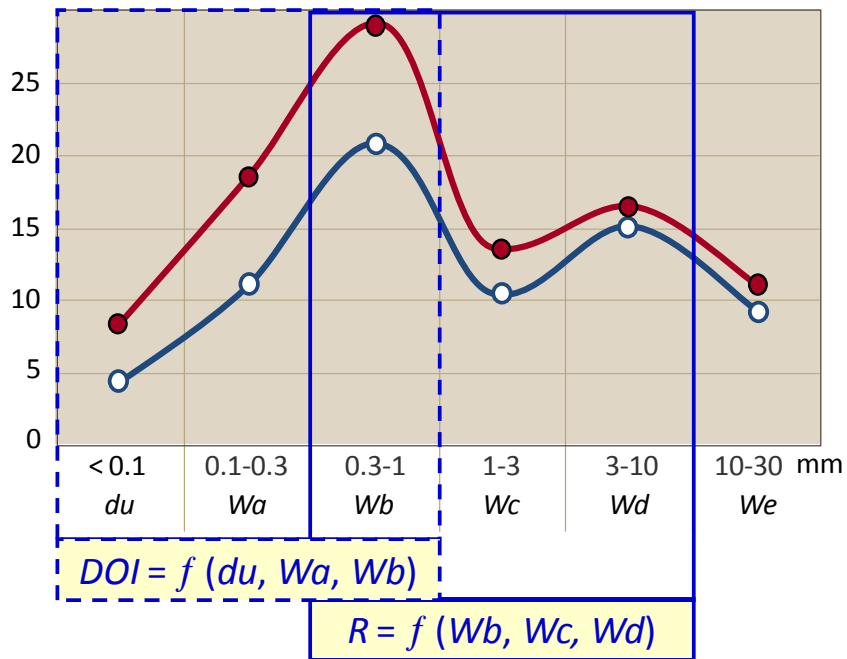


## Metallic Mottle

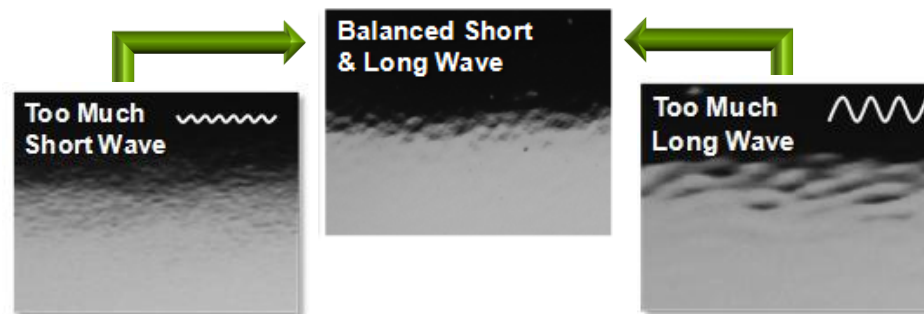
- Nominal Mottle “M” Value
- Mottle Spectrum

# Objective Instrumental Measurement: Exterior Surface Appearance

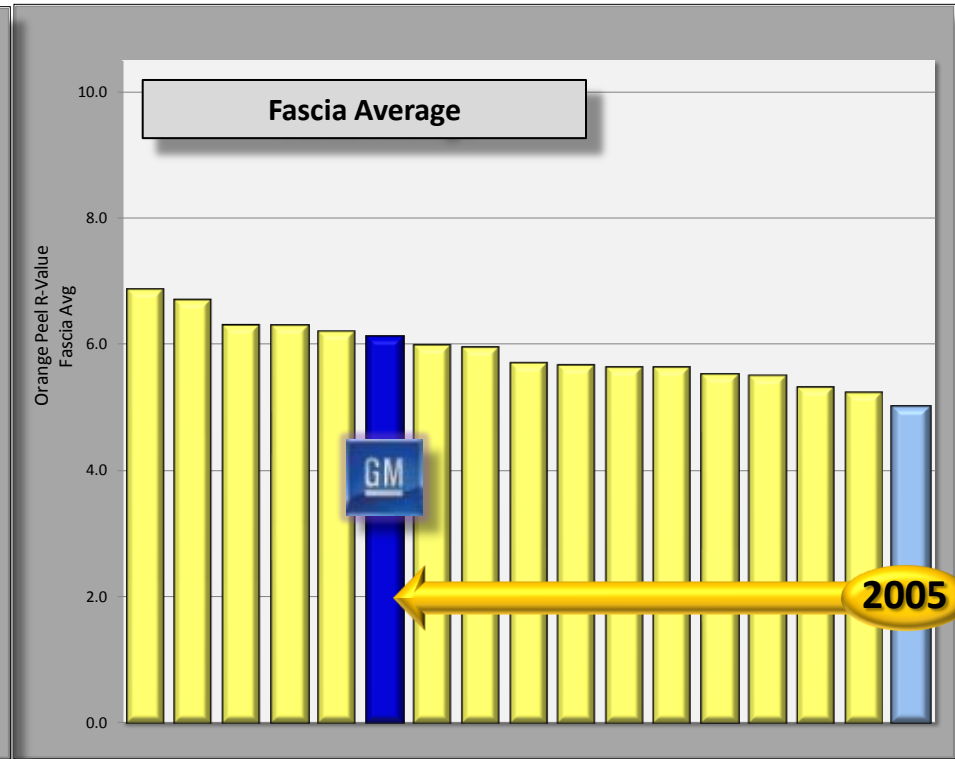
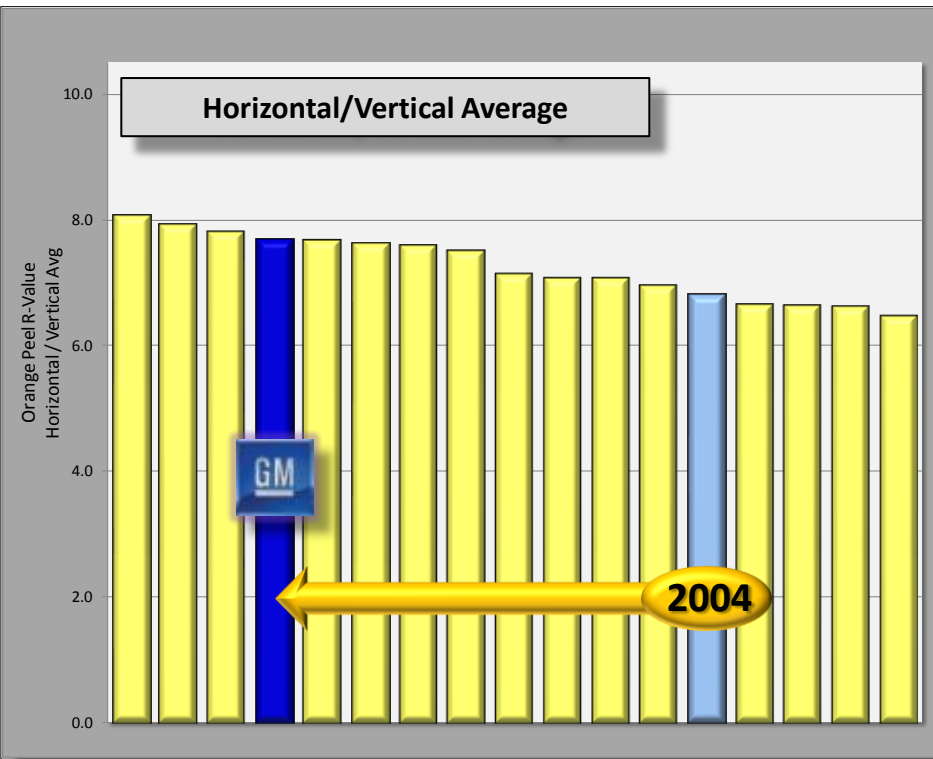
## Structure Spectrum



- ◆ Gage R&R Validated
- ◆ Optical Profile Generated by Laser Reflection
- ◆ Color Independent
- ◆ Objective WaveScan Characterized Surface Structure



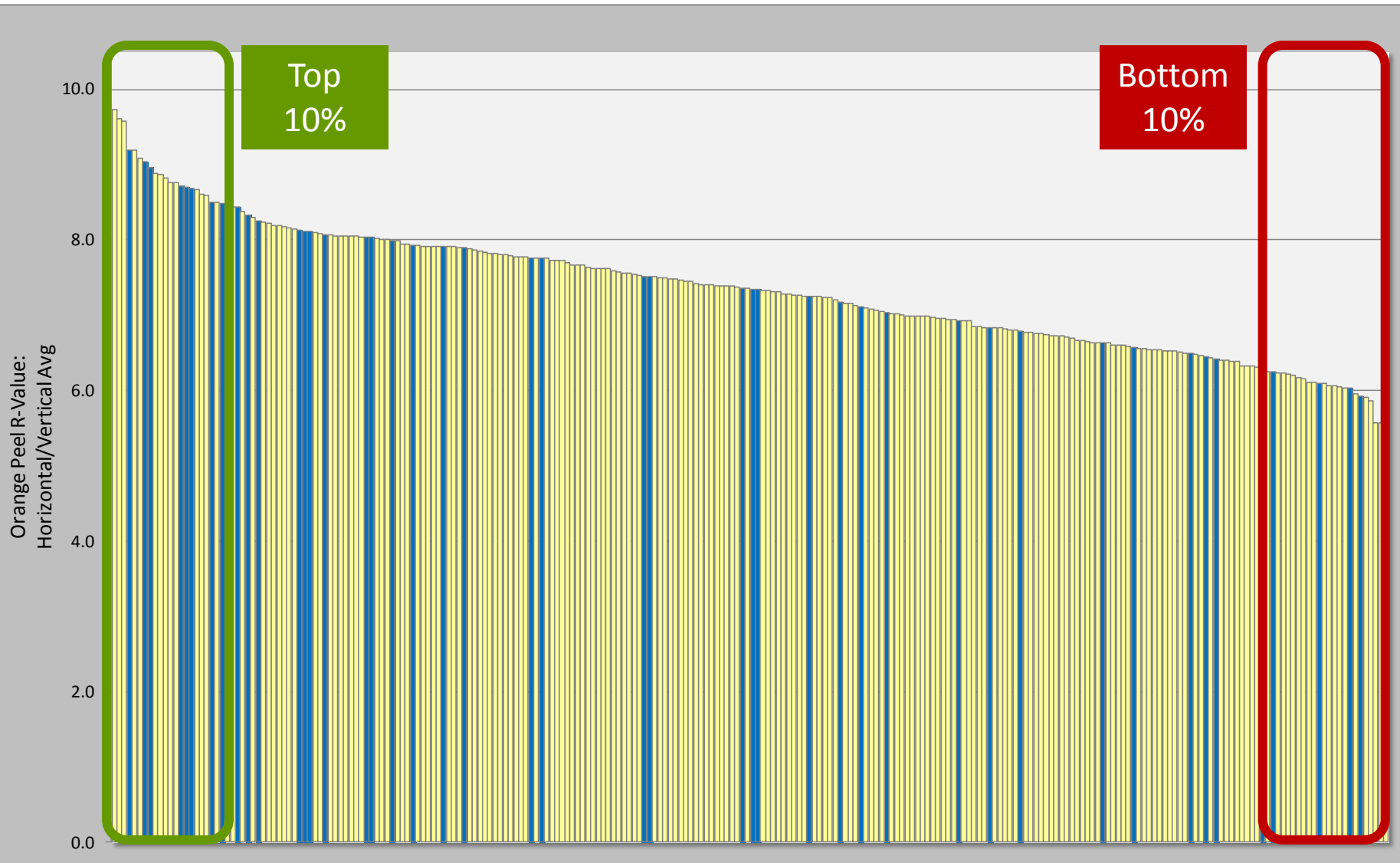
# Exterior Surface Appearance: NA OEM's - GM NA vs. Market



**You Can *Move* What You Can *Measure* !**

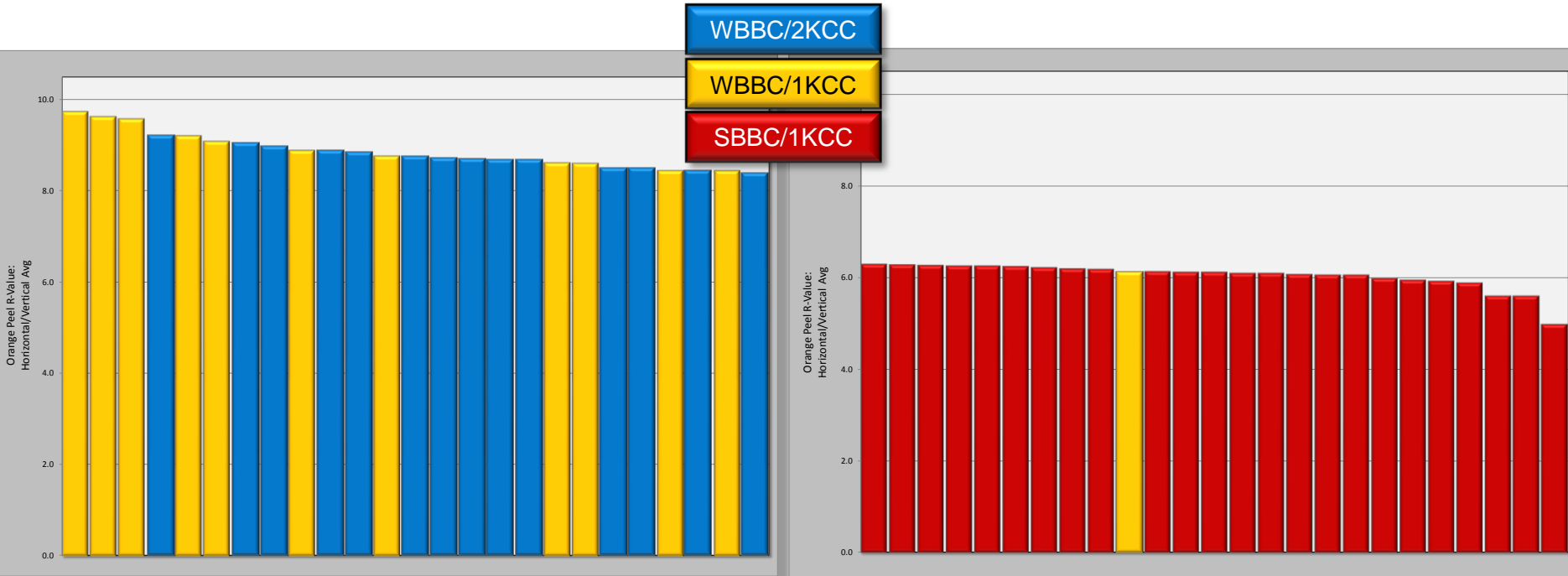


# NA Model Comparison - 250 Models: Horizontal / Vertical Average



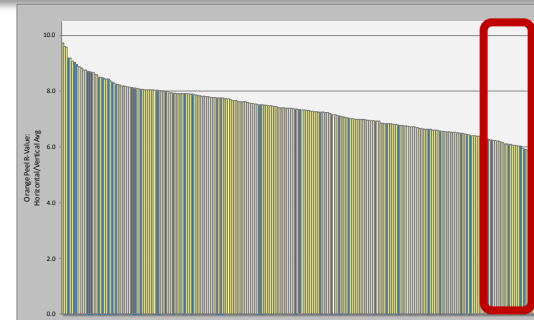
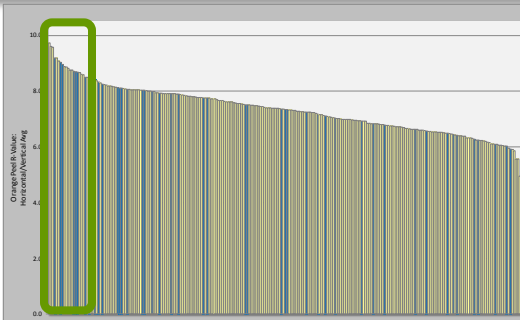


# NA Model Comparison - Top & Bottom 25: Horizontal / Vertical Average

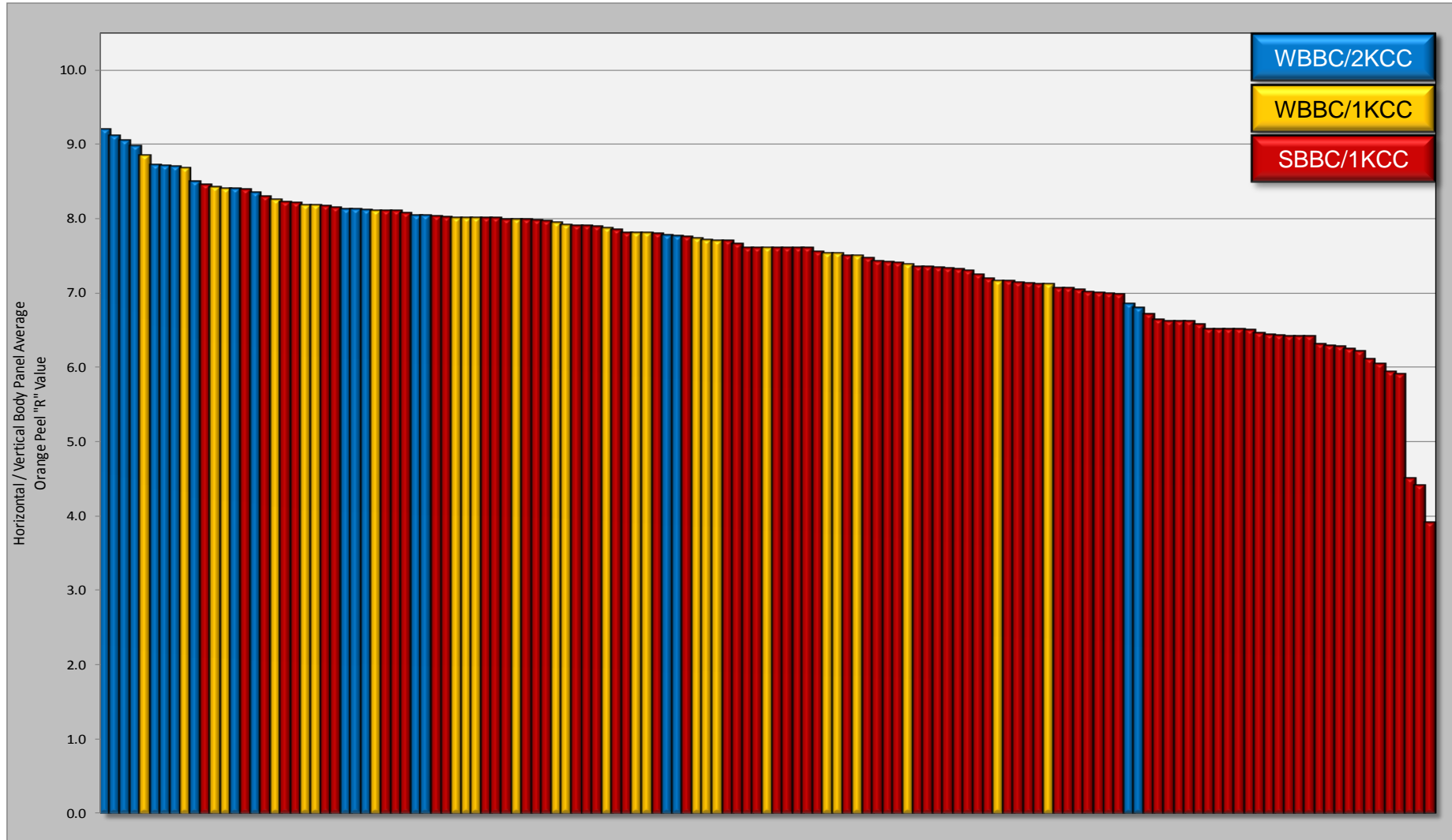


Top 25 Models:  
100% Waterborne Basecoat

Bottom 25 Models:  
96% Solventborne Basecoat



# Material Technology - GM Global Models: Horizontal / Vertical Average



# Objective Instrumental Measurement



## Exterior Surface Appearance

- Nominal Orange Peel “R” Value & Surface Uniformity
- Shortwave (SW), Longwave (LW), DOI
- Structure Spectrum (du-We) & Structure Balance (B)



## Color Harmony

- Fascia and Body to Standard
- Fascia to Body Harmony
- Supplement to Visual Harmony Reviews



## Metallic Mottle

- Nominal Mottle “M” Value
- Mottle Spectrum

# Objective Instrumental Measurement: Fascia to Body Color Harmony

**Non-chromatic:**

$$\Delta E_{\gamma}^2 = \left( \frac{\Delta L_{\gamma}}{g \cdot S_L \gamma} \right)^2 + \left( \frac{\Delta a_{\gamma}}{g \cdot S_a \gamma} \right)^2 + \left( \frac{\Delta b_{\gamma}}{g \cdot S_b \gamma} \right)^2$$



**Chromatic:**

$$\Delta E_{\gamma}^2 = \left( \frac{\Delta L_{\gamma}}{g \cdot S_L \gamma} \right)^2 + \left( \frac{\Delta C_{\gamma}}{g \cdot S_C \gamma} \right)^2 + \left( \frac{\Delta H_{\gamma}}{g \cdot S_H \gamma} \right)^2$$

$S_L = \frac{0.15\sqrt{L_{\gamma}} + \frac{31.5}{\gamma}}$   
 $S_C = \max\left(0.7, \frac{0.48\sqrt{C_{\gamma}} - 0.35\sqrt{L_{\gamma}} - \frac{42}{\gamma}}{\gamma}\right)$   
 $S_H = \max\left(0.7, \frac{0.7 + 0.14\sqrt{C_{\gamma}} - 0.20\sqrt{L_{\gamma}} - \frac{23}{\gamma}}{\gamma}\right)$

$S_L = \frac{0.15\sqrt{L_{\gamma}} + \frac{31.5}{\gamma}}$   
 $S_C = 0.7$   
 $S_H = 0.7$

Chromatic:  
 $C^* \geq 18$  or  
 $C^* \geq 10$  and  $L^* < 27$

- ◆ Gage R&R Validated
- ◆ Multi-Angle Color Measurement
- ◆ Metallic Impact Characterized by Sparkle and Graininess
- ◆ Objective Data for Match to Digital Master Standard
- ◆ Adjacent Panel Color Harmony

## Multi-angle Color Measurement



## Sparkle and Graininess Evaluation



Component to Component (Body to Fascia)

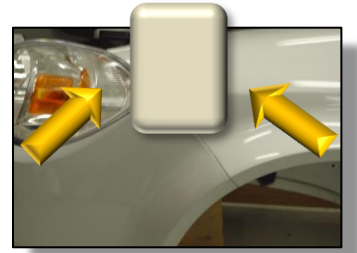


Supports Monthly Color Harmony Reviews

# BykMac Output

## Total Color Difference $\Delta SE$

Component to Master Certified Standard



Supports Paint Shop Process Control

$\Delta S$

$\Delta E$

Effect (Gonioapparent)

Color Difference

Sparkle

Graininess

25°, 45°, 75°

Angle Independent

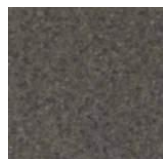


Bright Light

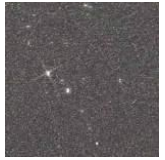
Diffuse Light



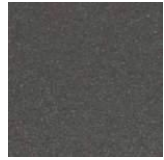
High Sparkle



High Graininess



Low Sparkle

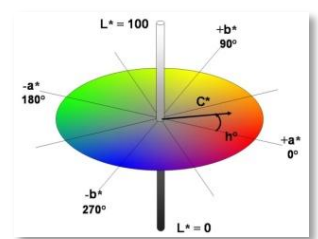
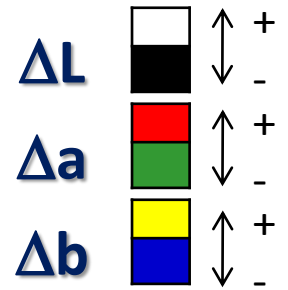
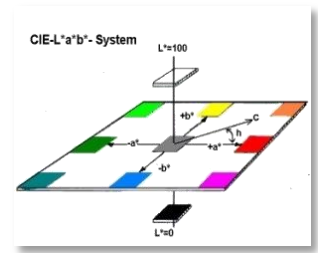


Low Graininess

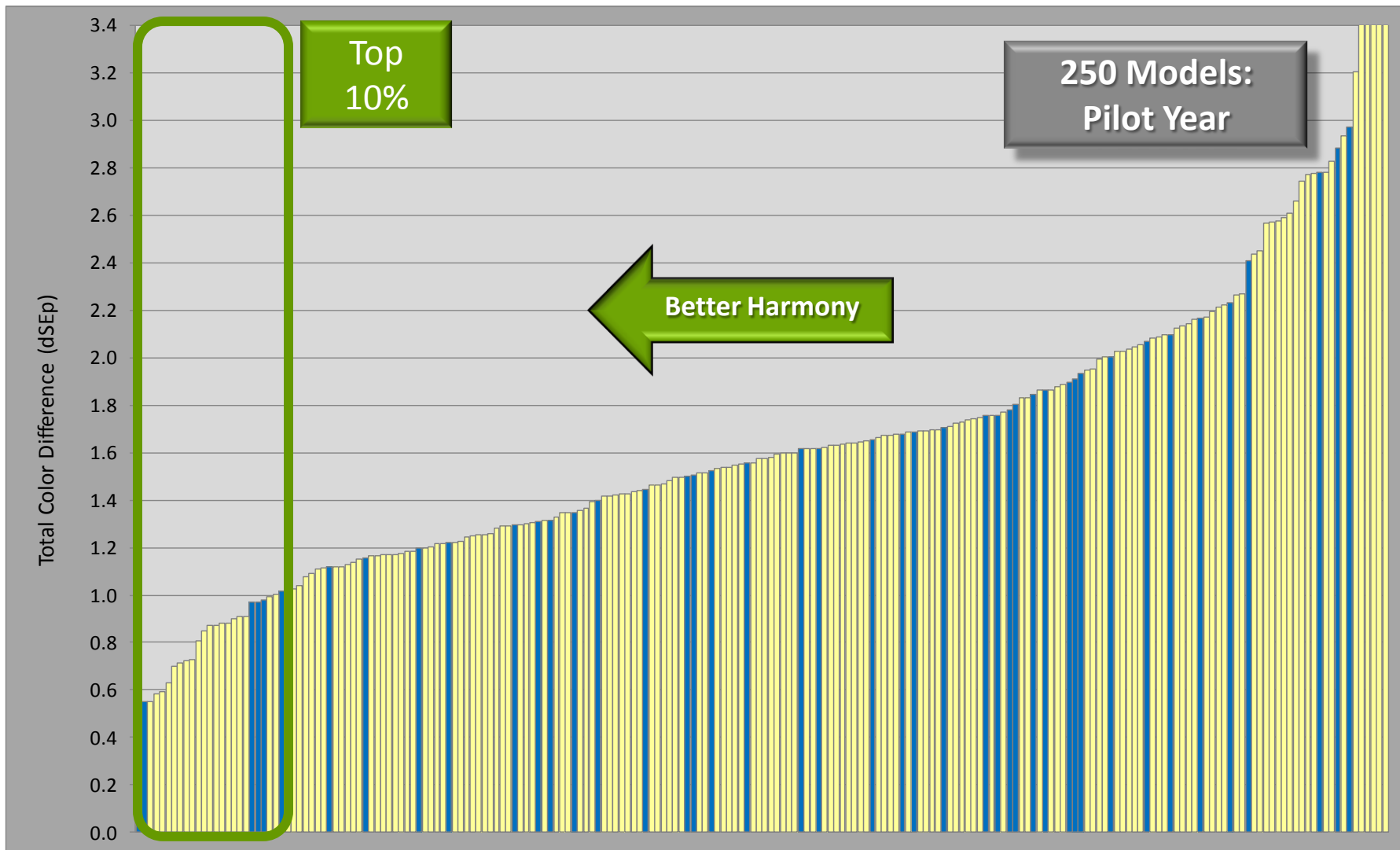
$S_a$  Sparkle Area  
 $S_i$  Sparkle Intensity

$G$  Graininess  
(Fine vs. Grainy Pattern)

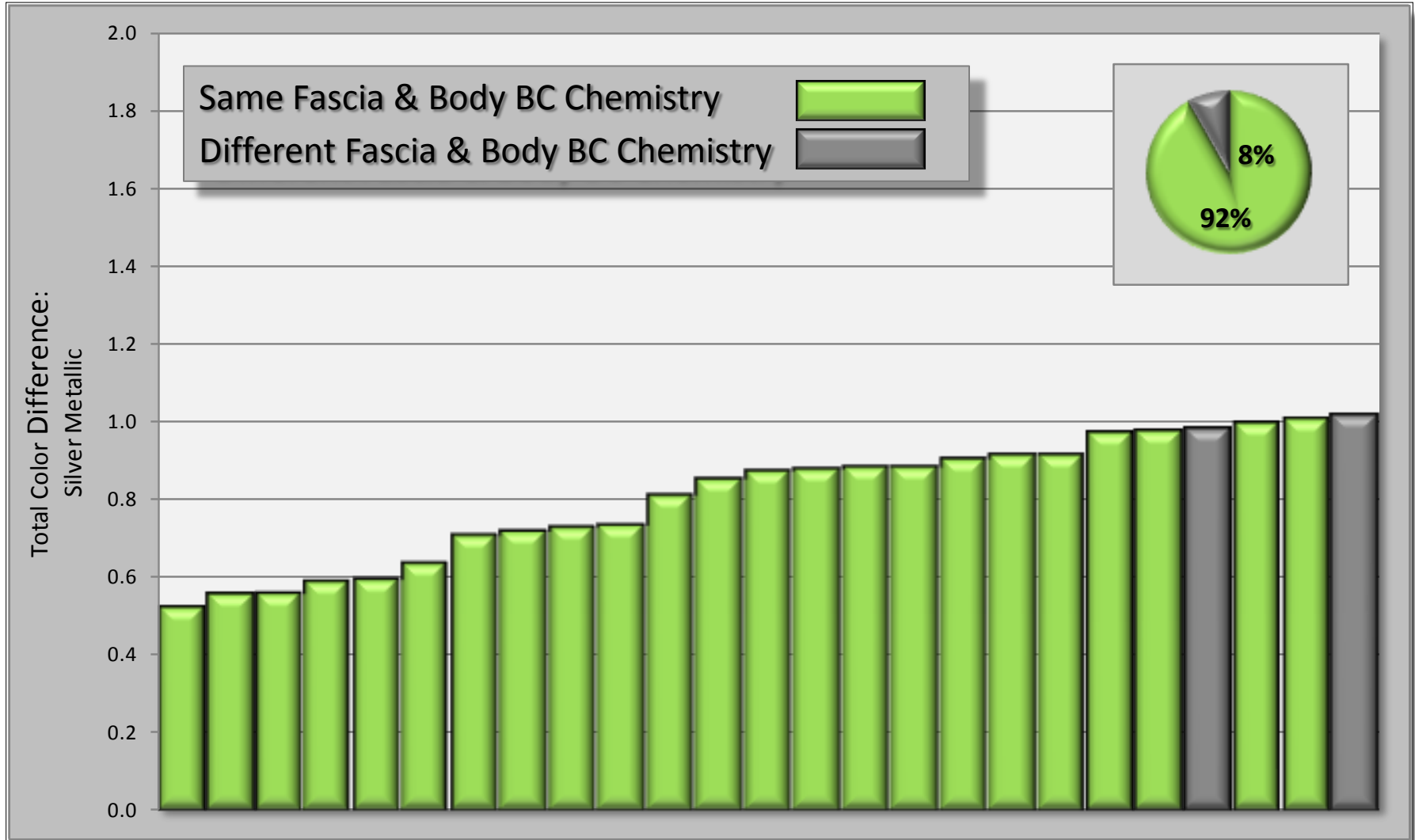
-15°, 15°, 25°, 45°, 75°, 110°



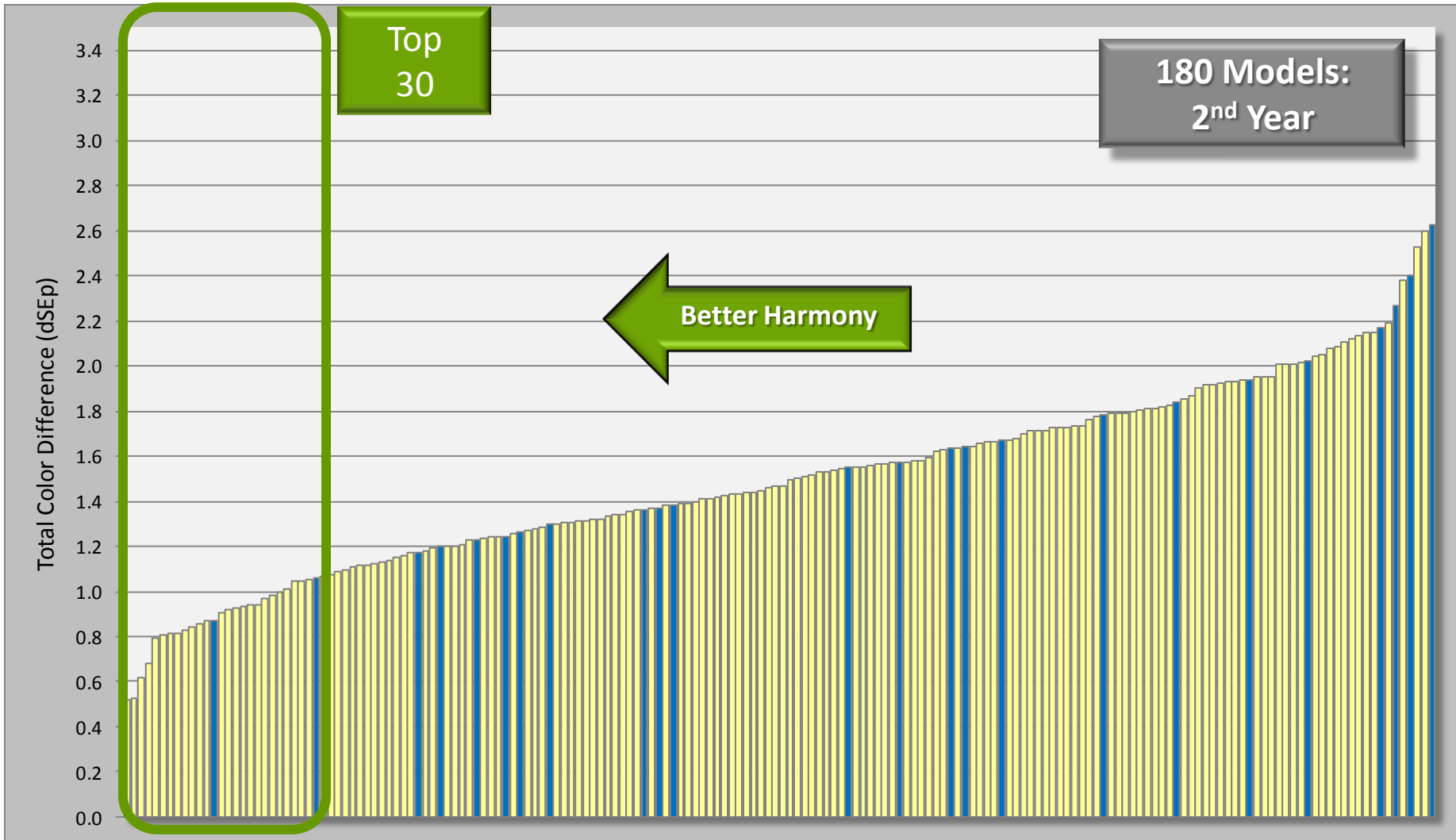
# NA Model Comparison - Light Metallic: Fascia to Body Color Harmony



# NA Model Comparison - Light Metallic: Top 10% - Fascia to Body Color Harmony

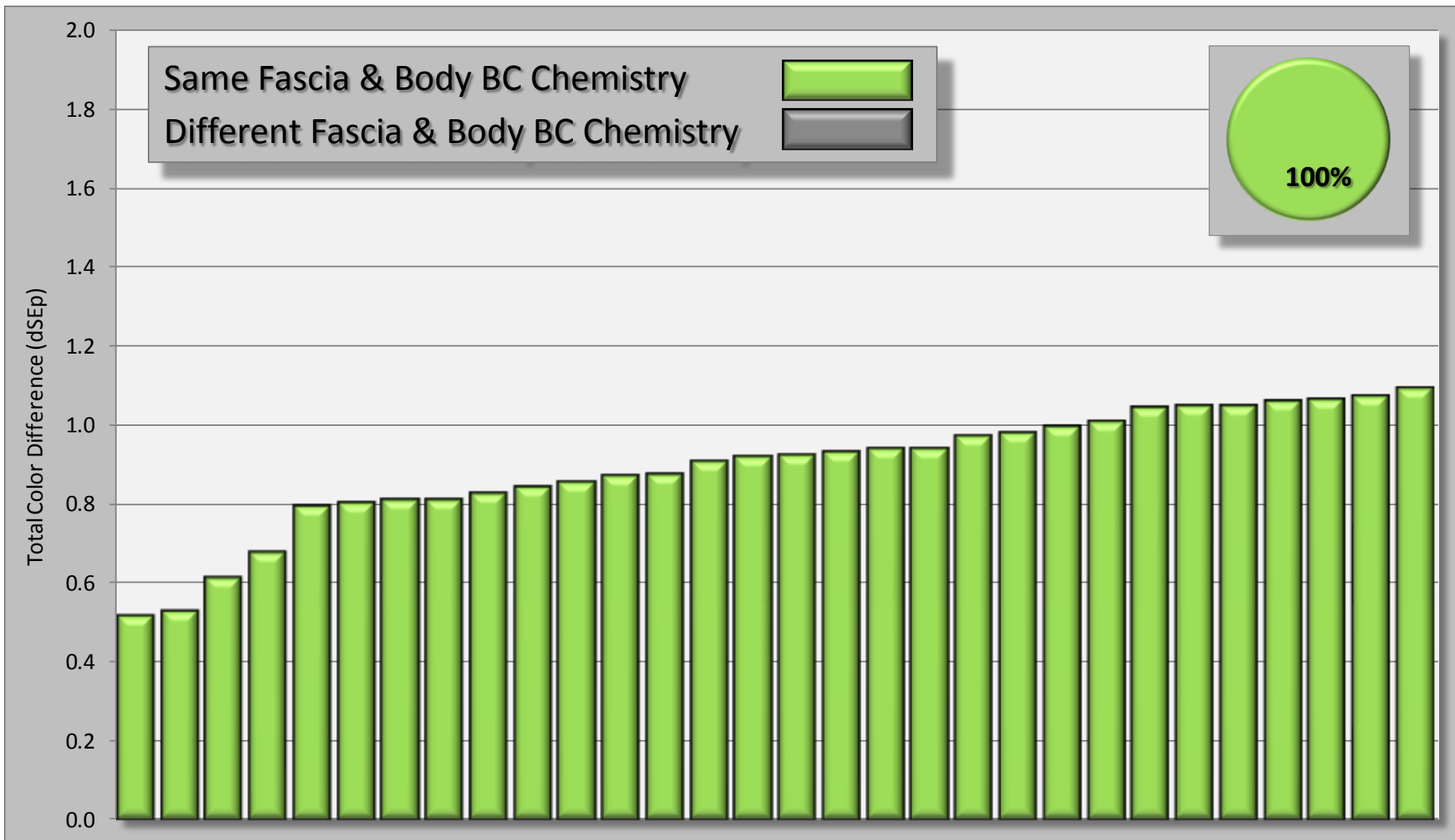


# NA Model Comparison - Light Metallic: Fascia to Body Color Harmony





# NA Model Comparison - Light Metallic: Top 30 - Fascia to Body Harmony



# Objective Instrumental Measurement



## Exterior Surface Appearance

- Nominal Orange Peel “R” Value & Surface Uniformity
- Shortwave (SW), Longwave (LW), DOI
- Structure Spectrum (du-We) & Structure Balance (B)



## Color Harmony

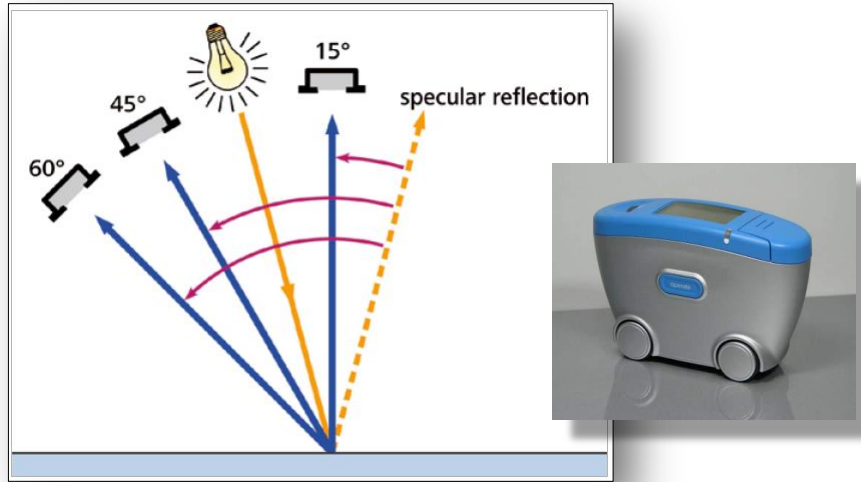
- Fascia and Body to Standard
- Fascia to Body Harmony
- Supplement to Visual Harmony Reviews



## Metallic Mottle

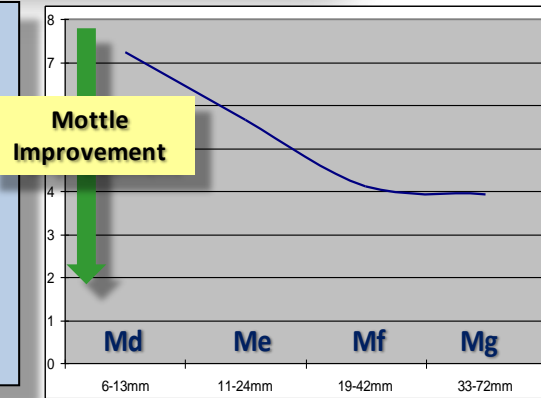
- Nominal Mottle “M” Value
- Mottle Spectrum

# Objective Instrumental Measurement: Metallic Mottling



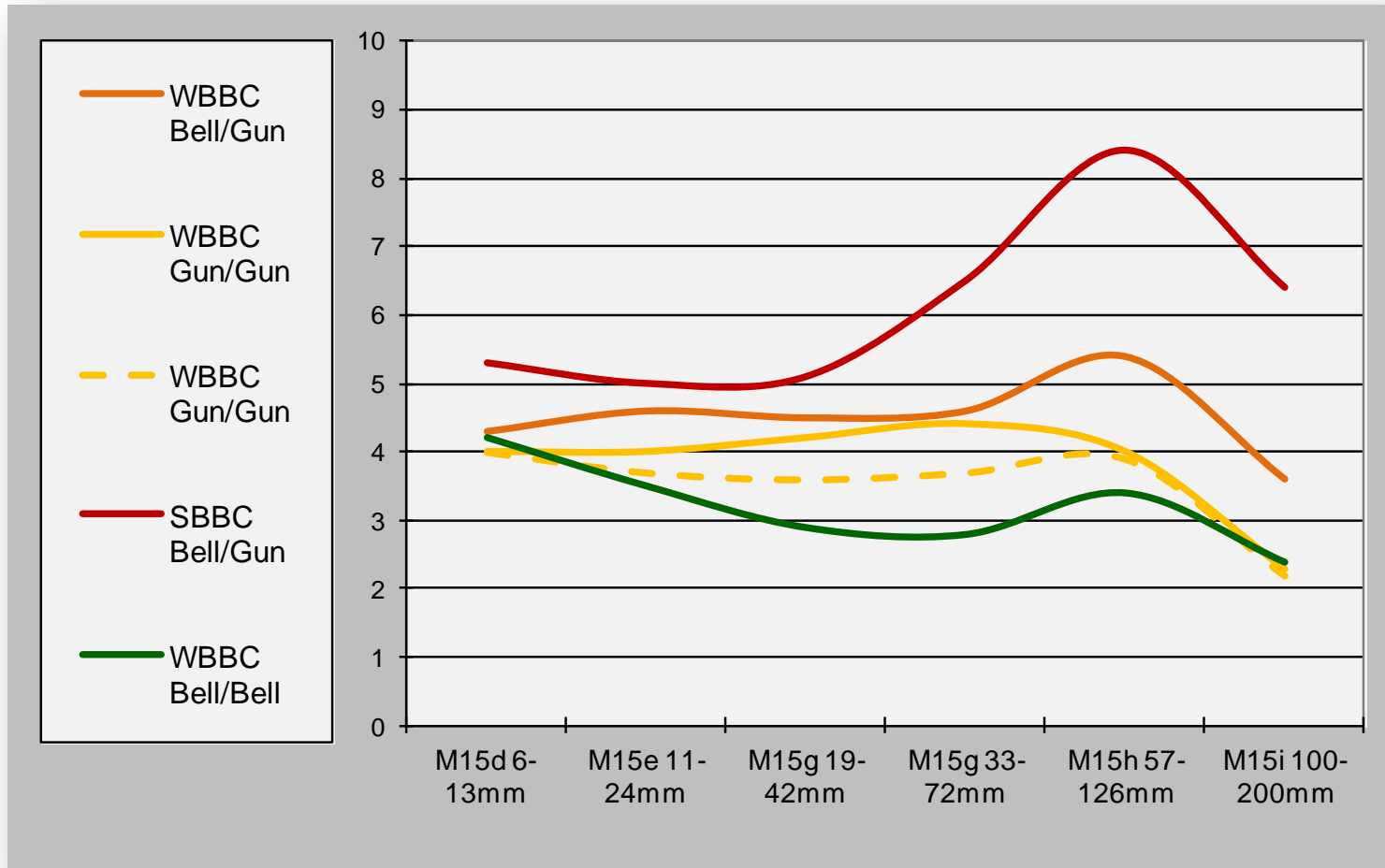
The Signal is Separated  
by Mathematical Filters:

	CLOUD SIZE
Md	6 - 13 mm
Me	11 - 24 mm
Mf	19 - 42 mm
Mg	33 - 72 mm
Mh	57 - 126 mm
Mi	100 - 200 mm



- ◆ Subjective Visual Evaluation Dependent on Illumination Conditions, Observation Distance, and Viewing Angle
- ◆ Objective Evaluation Mottling (Lightness Variation) Possible over Large Areas at Different Angles, Independent of Illumination Conditions

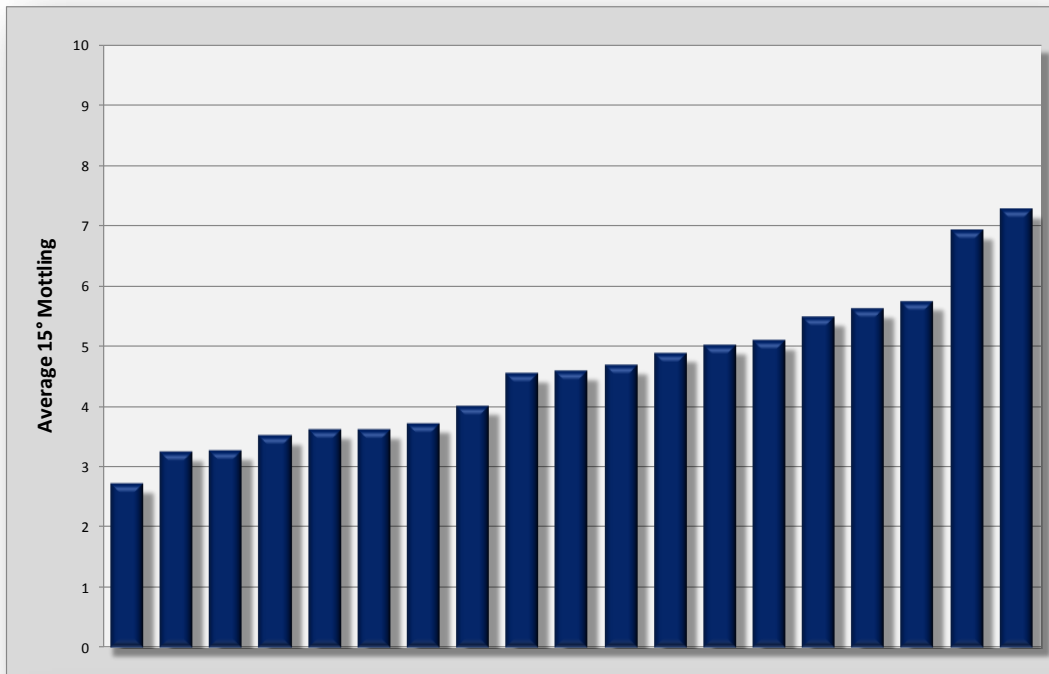
# Select GM NA Models – Light Tri-Coat: 15° Mottle



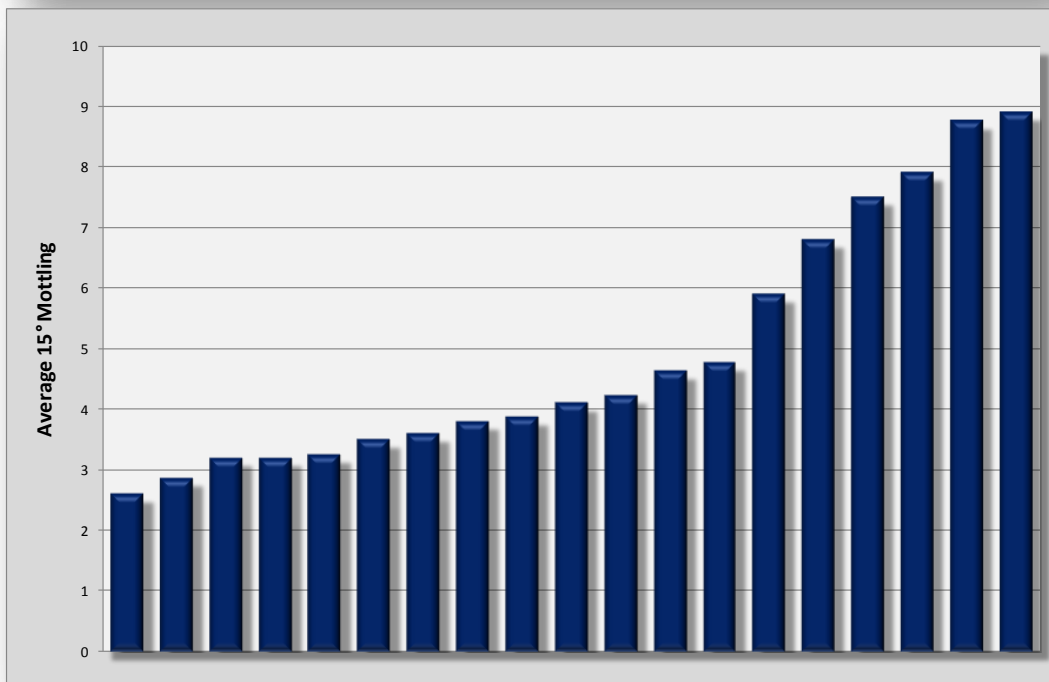
Vertical: Left Front Door Upper



# GM NA Models – Light Tri-Coat: 15° Mottle

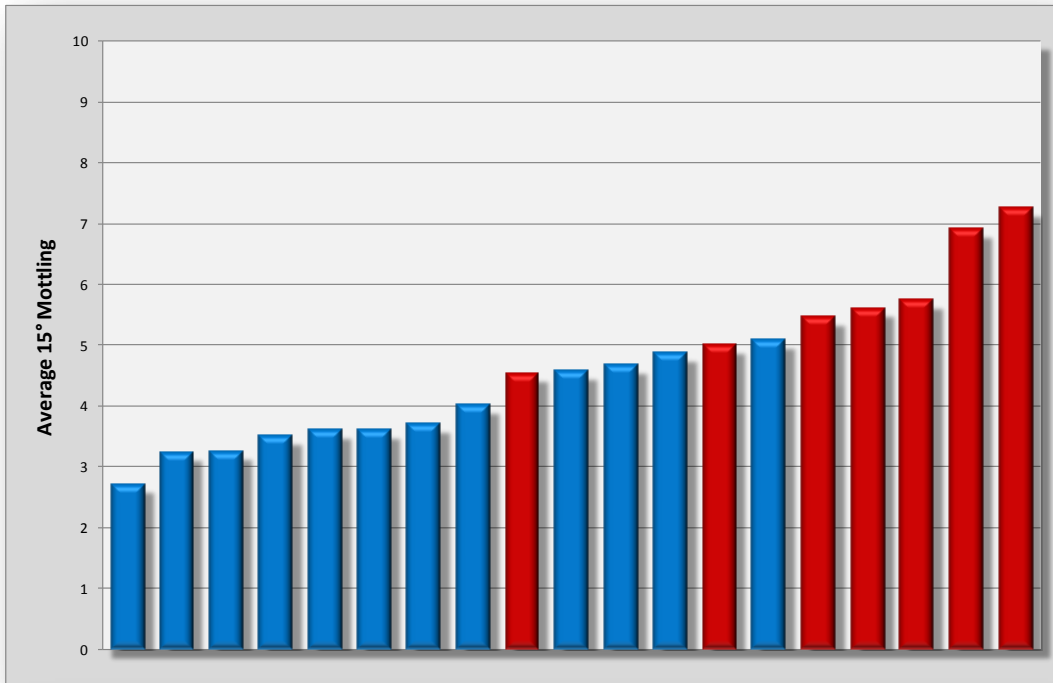


Vertical:  
Left Front Door Upper



Horizontal:  
Left Front Hood Forward

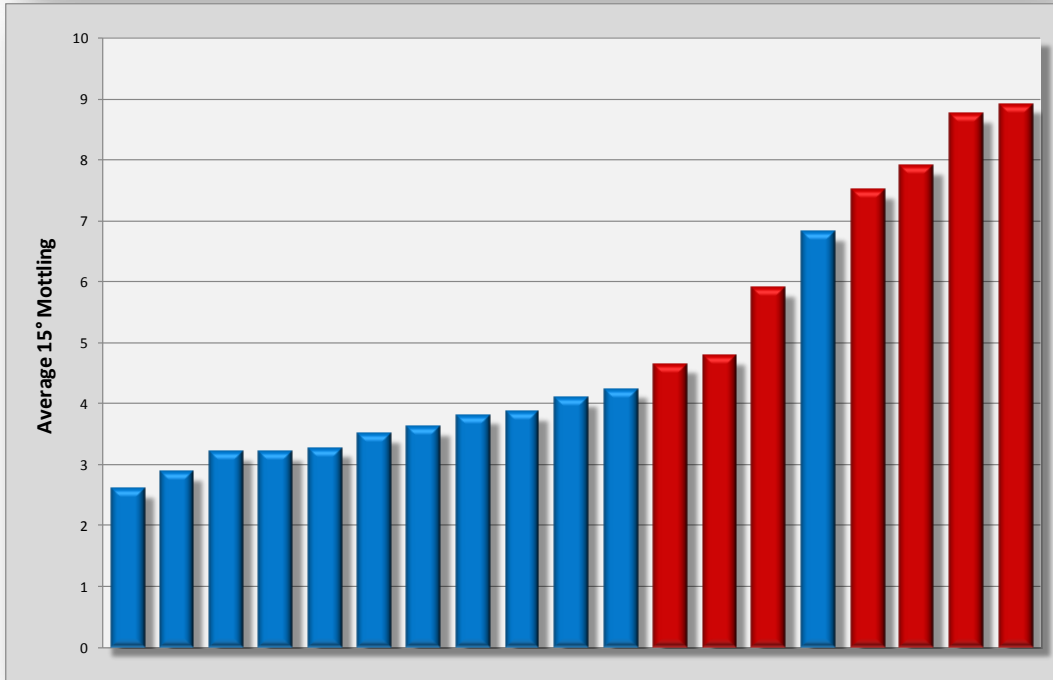
# GM NA Models – Light Tri-Coat: 15° Mottle



Vertical:  
Left Front Door Upper

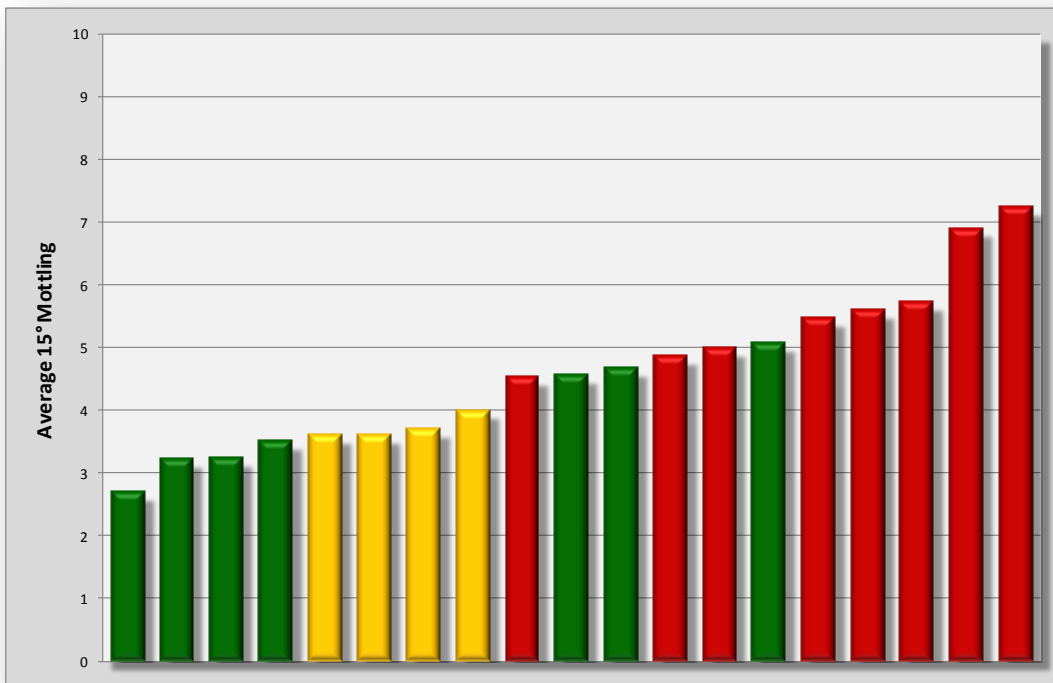
WBBC

SBBC



Horizontal:  
Left Front Hood Forward

# GM NA Models – Light Tri-Coat: 15° Mottle

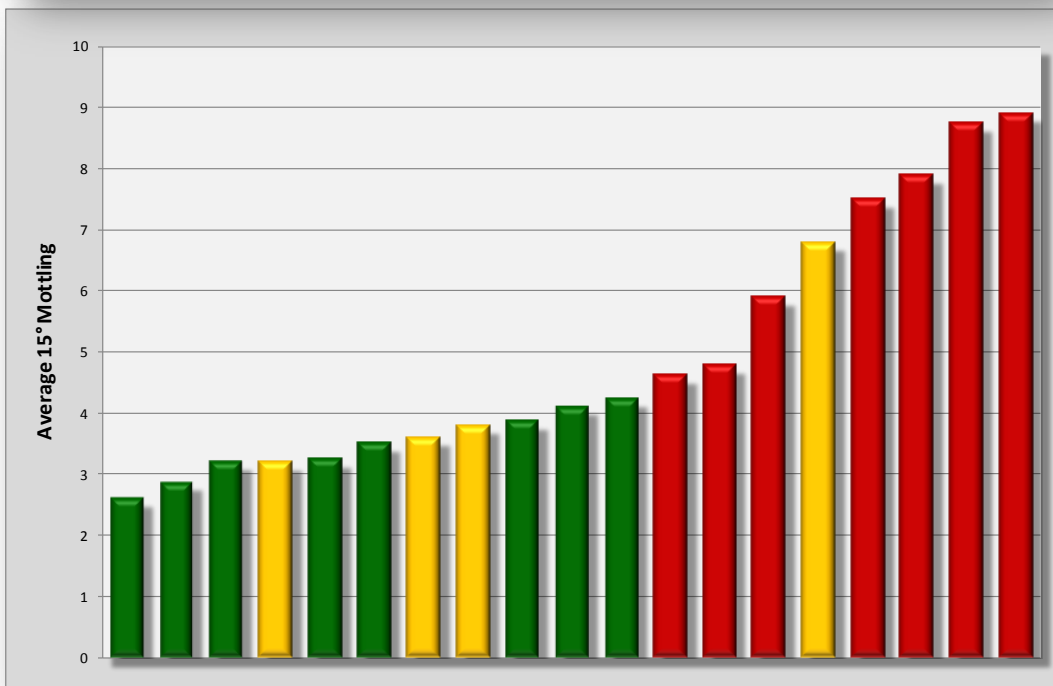


Vertical:  
Left Front Door Upper

Bell / Bell

Gun / Gun

Bell / Gun



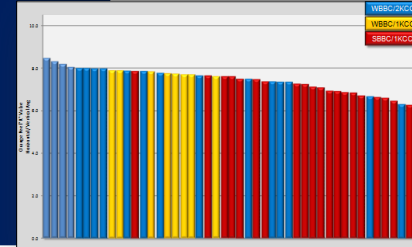
Horizontal:  
Left Front Hood Forward

# Objective Instrumental Measurement



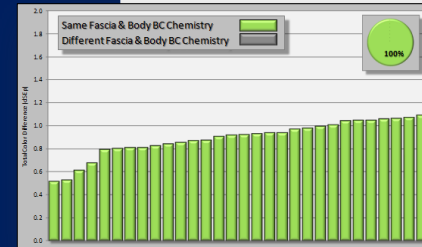
## Exterior Surface Appearance

- Nominal Orange Peel “R” Value & Surface Uniformity
- Shortwave (SW), Longwave (LW), DOI
- Structure Spectrum (du-We) & Structure Balance (B)



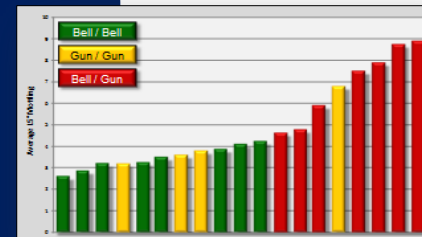
## Color Harmony

- Fascia and Body to Standard
- Fascia to Body Harmony
- Supplement to Visual Harmony Reviews



## Metallic Mottle

- Nominal Mottle “M” Value
- Mottle Spectrum





# Capturing the Perceptual Quality of Coatings: Business, Science, Opportunity

- ◆ Objective Instrumental Measurement
- ◆ Correlation with Customer Input
- ◆ Analysis and Definition of Targets
  - *Definition of Market Segment Targets*
  - *Benchmarking by Segment / Country / Region*
  - *Use SPC Tools to Determine Triggers*
- ◆ Business Case Options Overlaid with Data
  - *Potential Plans for Processes, Products, Technologies*



*From an Emotional Response to Engineering Analysis*

