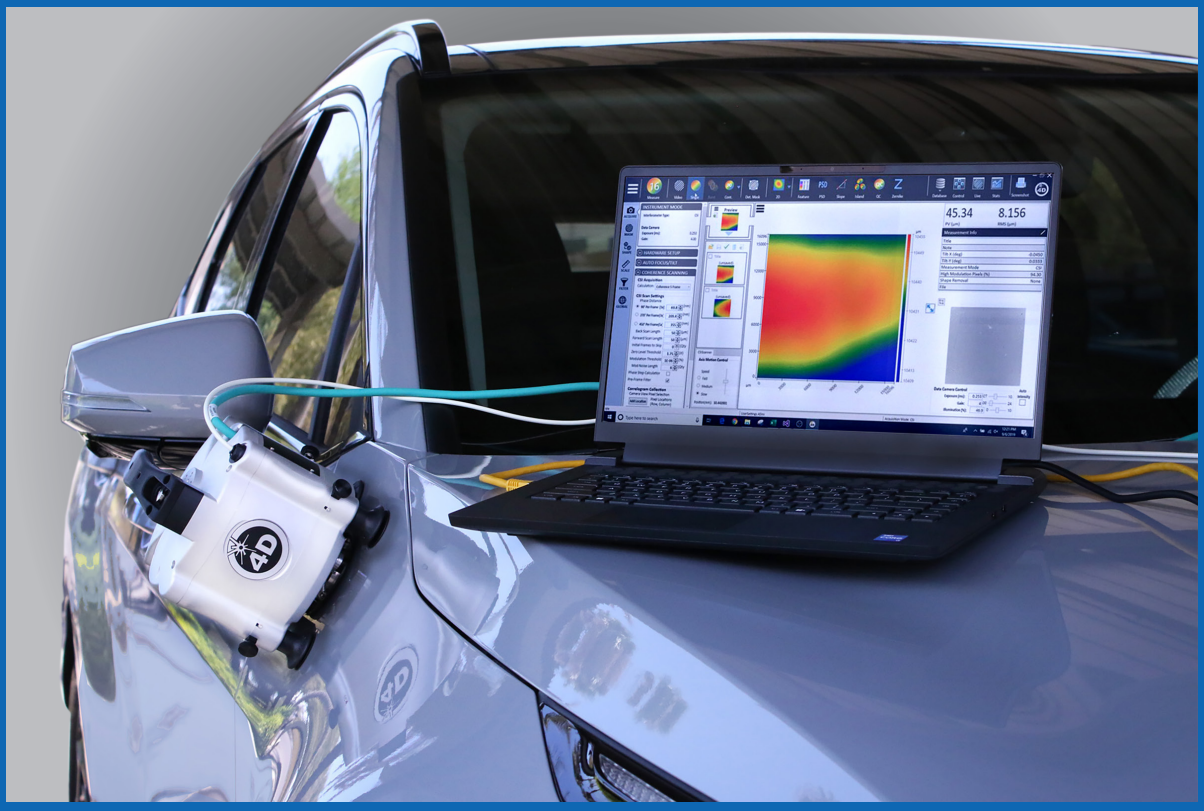


Measuring Auto Surfaces from Substrate to Clear Coat

Tracking automotive finish processes to ensure quality and reduce scrap

4D Technology

An Onto Innovation Subsidiary

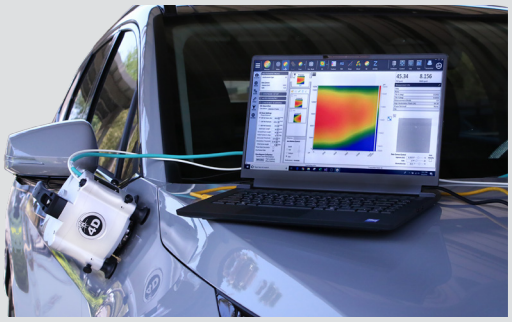
Table of Contents

Using interferometry to measure surfaces with high precision

For years, automotive manufacturers have only been able to verify the quality of paints and coatings after completing the entire process. Without a method to track the quality of paint finishes from end-to-end of the coating process, components continue through manufacturing, accruing greater and greater value, before ultimately being scrapped after the final coat.

Industry and metrology professionals have called for a new production measurement system to correlate the surface texture at each step in the painting process with final paint quality. This new instrument, 4D SurfSpec™, can “fingerprint” their coating processes, identifying issues early in the process that will lead to poor final finishes.

This paper discusses the first handheld, shop floor system for rapid measurement of bare substrates and coating layers on almost any surface texture or material. 4D SurfSpec provides ongoing process feedback to improve quality and reduce costs.



Learn more and download datasheet:

4D SurfSpec Data Sheet

Measuring Auto Paint from Substrate Through Clearcoat

By Erik Novak and Mike Zecchino

Auto manufacturers require a method for controlling paint appearance, and for removing parts early in the process that will lead to poor finish.

Industry and metrology professionals have called for a new production measurement system to correlate the surface texture at each step in the painting process to final paint quality. This new instrument can "fingerprint" coating processes, identifying issues early in the process that will lead to poor final finishes.

Why Paint Finish Matters

For an automobile buyer, first impressions are critical. Does the car feel well built? Does it handle smoothly and feel that it will last? And, perhaps most importantly: does it look great?

Buyers equate a quality finish with a quality vehicle. What constitutes a "quality" paint finish is, of course, subjective, to an extent. Yet, the vast majority of buyers would reject a car with mismatched panels as in Figure 1, or with a finish exhibiting orange peel, haze, pits, or dings.

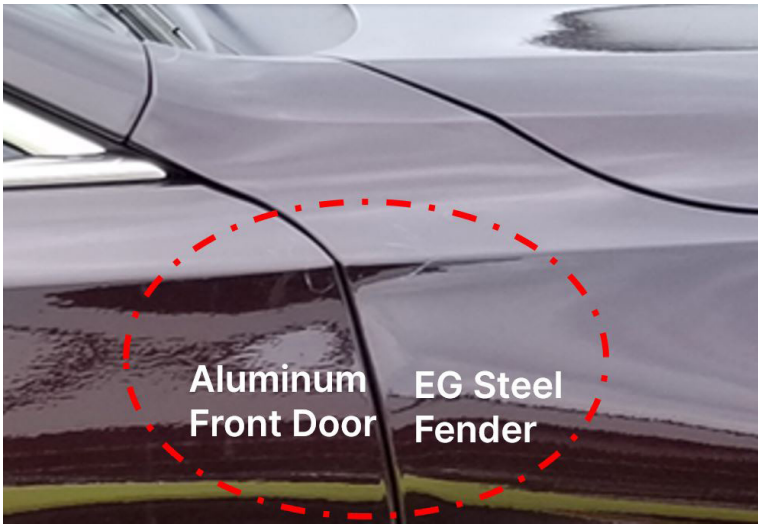


Figure 1. Current methods. An aluminum panel next to steel panel show clear texture differences. Courtesy of General Motors.

1. Costs

A good impression is important, but manufacturers have more at stake. Paint and coatings account for approximately 30% of a vehicle's total production cost, factoring in the associated energy, capital, and environmental costs.Paint also accounts for up to 70% of an assembly facility's energy requirements. Scrapping coated parts late in the process drains resources.

2. Varying Substrates

The growing variety of substrates adds to painting complexity. Raw sheet steel, zinc plated steels, aluminum, plastics, composites, and additive materials each react differently to the same coating process. Providing a consistent finish across these materials is a significant challenge—and one that is not always met. According to the NHTSA.gov website, more than

The automotive industry has pushed for the development of a system for end-to-end metrology of paint processes.

twenty-five recalls have occurred since 2000 due to paint quality issues, costing millions of dollars in direct costs as well as impacting customer perception and brand loyalty.

Controlling Final Paint Appearance Is Not Enough

Auto manufacturers require a method for controlling paint appearance, and for removing parts early in the process that will lead to poor finish.

The surface texture determines, to a large extent, how the human eye will perceive paint appearance. Surface texture consists of a spectrum of spatial wavelengths, ranging from short-wavelength roughness through longer-wavelength waviness and form. Various wavelength bands reflect light differently, and research has identified several key bands that most affect our assessment of a coated surface (Figure 2). Aspects such as haze, roping, and orange peel can be attributed to particular bands of spatial wavelengths. Manufacturers have developed individual recipes for the acceptable height amplitudes in each of these bands that, together, will constitute a "quality" finish.

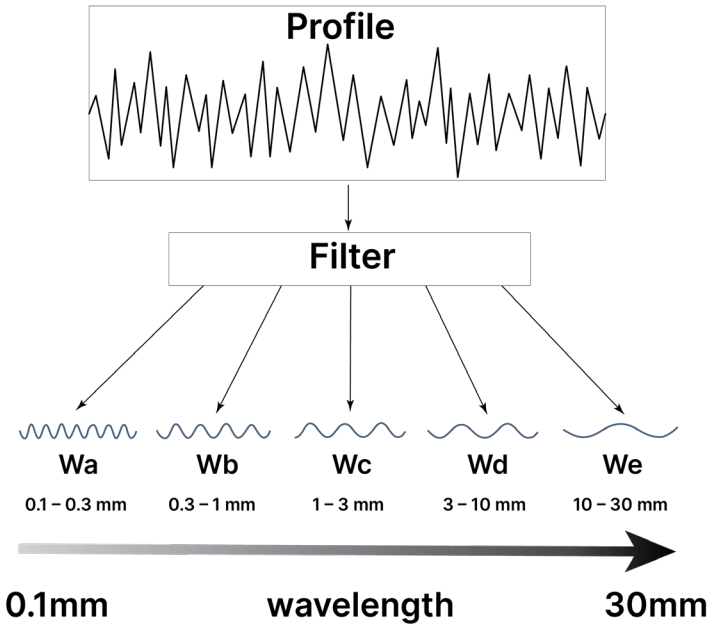


Figure 2. Five bands of spatial wavelengths that matter for paint appearance (Courtesy Michigan Metrology).

Limitations of Other Methods

Other measurement systems can characterize these critical wavelength bands, but only for a final painted surface. These "shininess gages" cannot measure the rougher texture of substrates, or intermediate coats. As we discussed earlier, rejecting a component, assembly, or vehicle after final coating means losing all its value.

When a paint system can only be verified at the end of the process, it is impossible to understand where the failure occurred along the way. Every layer of a paint system influences subsequent layers, making it imperative to track the entire process.

As manufacturers strive to implement Industry 4.0 (the integration and automation of systems and data throughout the factory), they need to be able to identify and address coating issues in real time, at every step of the process, using timely and relevant data.

To track the entire paint process, an instrument must be able to measure both rough substrates and fine coating textures.

End-to-End Coating Process Control

Over the past several years, the automotive industry has pushed for the development of a system for end-to-end metrology of auto paint processes. Such a system would benefit not only auto manufacturers, but also substrate and sub-assembly suppliers who can ensure that their product will not be returned for quality issues.

The industry requirements developed for the system include[1]:

- a large field of view to quantify structures up to 5 mm wide (the scale of features to which the human eye is sensitive)
- the ability to measure lateral dimensions as small as 20 µm
- vertical resolution of 30 nm or better to ensure adequate measurements of final paint
- capability to also measure rough surfaces of up to 1 µm RMS roughness
- short measurement time
- robustness to harsh environments
- ease of use
- operator-independent results.

Most critically, the system must be able to measure both rough substrates and fine coating textures to track the entire process. Using one measurement technology throughout is essential, because correlating results between technologies is extremely difficult. Spatial and vertical resolution, sensitivity to environmental effects, and measurement times all vary between technologies, and even between instrument brands[2]. It becomes nearly impossible to distinguish the effects of the instrumentation from the actual process variability.

The 4D SurfSpec system (Figure 3) meets these requirements for a single, end-to-end process measurement solution. This portable system measures surface texture at every stage of the coating process, *in situ* on the production floor. Using "coherence scanning interferometry[3]" to acquire 3D surface texture measurements of both rough and smooth surfaces, the compact instrument (approx. 150 mm on a side) achieves nanometer-scale vertical resolution, with a large, 16 × 16 mm field to characterize the feature scales important to appearance.

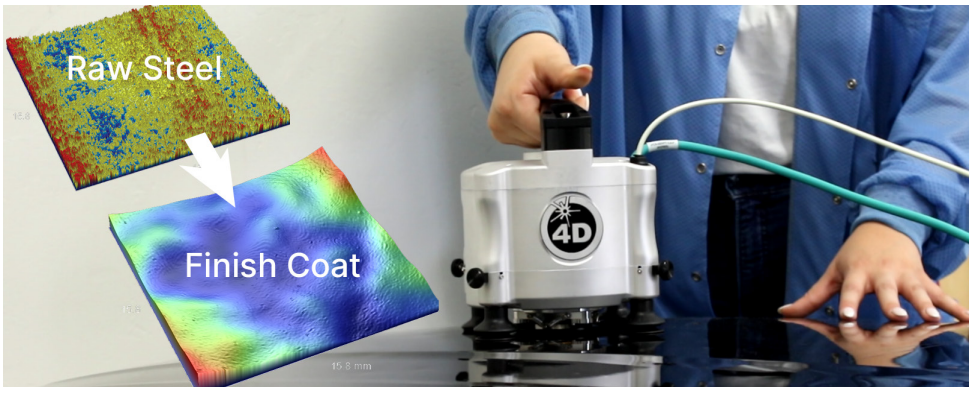


Figure 3. The 4D SurfSpec system was developed with industry experts to fingerprint the entire automotive coating process. 3D, false-color height measurements of EG steel, and gloss coat, surface roughness is shown at left.

The measurement/analysis cycle with the new instrument requires less than 30 seconds, so inspectors can use it for real-time process control. It can be hand-positioned or robot-mounted for measurement in any orientation, with vacuum feet to couple the system to the test component.

End-to-end metrology also benefits substrate suppliers, who can ensure that their product will not be returned for quality issues.

Fingerprinting the Coating Process

"Fingerprinting" a paint process determines the requirements of each coating layer to produce a successful final appearance. The 4D SurfSpec provides the necessary data to fingerprint a process so that inspectors can achieve the required quality during:

- sheet metal production
- stamping
- closure assembly
- body-in-white
- pre-paint
- E-coat
- paint
- clearcoat, and
- final quality stages.

Inspectors can analyze the 3D measurement data in real time to differentiate passing and failing components. As part of that analysis, the data is "filtered" into the spatial wavelength bands that are important for appearance. The 4D SurfSpec includes built-in capability to perform this kind of analysis. Optionally, data can be exported to Bandify3D software (Digital Metrology Solutions) to provide comprehensive filtering analysis.

Figure 4 shows the power of filtering. The images on the left show four aluminum samples which cannot be differentiated visually. Even parameters such as average surface roughness (Sa), using a standard 0.8 mm filter, give very similar values for all the surfaces. However, after being filtered into wavelength bands, the data reveals both visual and numerical differences between the samples. We see an increasing levels of roping, with the two samples on the right producing unacceptable final paint quality. 3D measurement and analysis make it possible to remove and rework these two parts, saving further production cost.

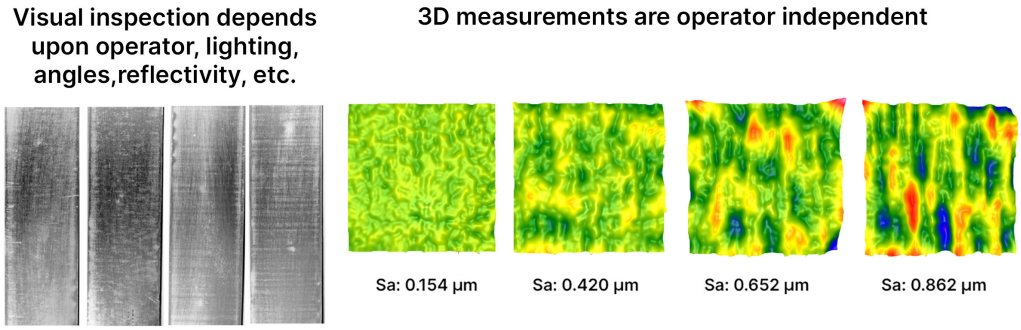


Figure 4: Four aluminum surfaces (left) appear similar in texture. However, filtering the 3D data into wavelength bands (right) reveals increasing degrees of roping. Results shown in Bandify3D software. Data and analysis courtesy General Motors.

Through fingerprinting, manufacturers develop specifications for each coating layer, based on correlation to final appearance rather. Figure 5 shows four 3D measurements of substrates above, along with the corresponding final coated surfaces below. The substrate measurements appear quite similar, the spatial scales of the features on the painted panels differ significantly. Data from the 4D SurfSpec enables manufacturers to set targets for substrate, to pass or reject parts, even before the coating process begins.

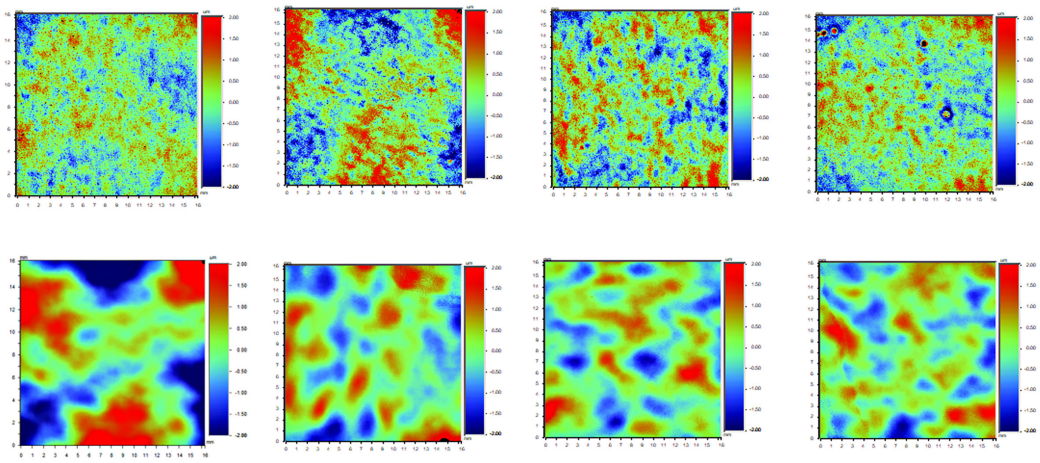


Figure 5: Four substrates (top) and final painted product (bottom). All measurements use the same false-color height scale.

Figure 6 shows how fingerprinting works. Analyzing the short wavelengths of Band 1 (left) does not show any correlation between the substrate measurement and final quality. However, examining the mid-spatial wavelengths in Band 2 does show a higher degree of correlation (right).

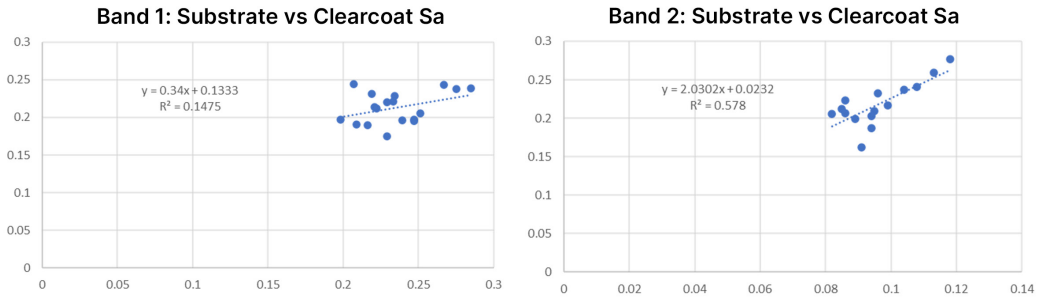
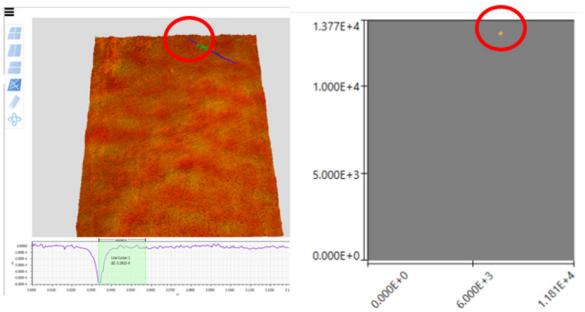


Figure 6: While analyzing one wavelength band does not differentiate this set of substrates (left), analyzing a different band shows a higher degree of correlation (right).

Locating and Quantifying Defects

The human eye seizes on small blemishes such as pits even more readily than the overall texture. When these defects appear early in the process, inspectors tend to reject the part based on the speculation that the defects will survive through to the final coat. Since visual inspection is poor for identifying the dimensions of small defects, inspectors must err far on the side of caution, meaning they scrap parts that would ultimately lead to acceptable finishes.

The 4D SurfSpec, however, readily quantifies pits, scratches, etc., and automatically reports the dimensions of the defects (Figure 7). As with overall texture, the quantity and size of defects can be correlated to final painted quality. Numerical thresholds for defects can be developed, allowing inspectors to objectively bin parts, increasing yield and avoiding unnecessary scrap.

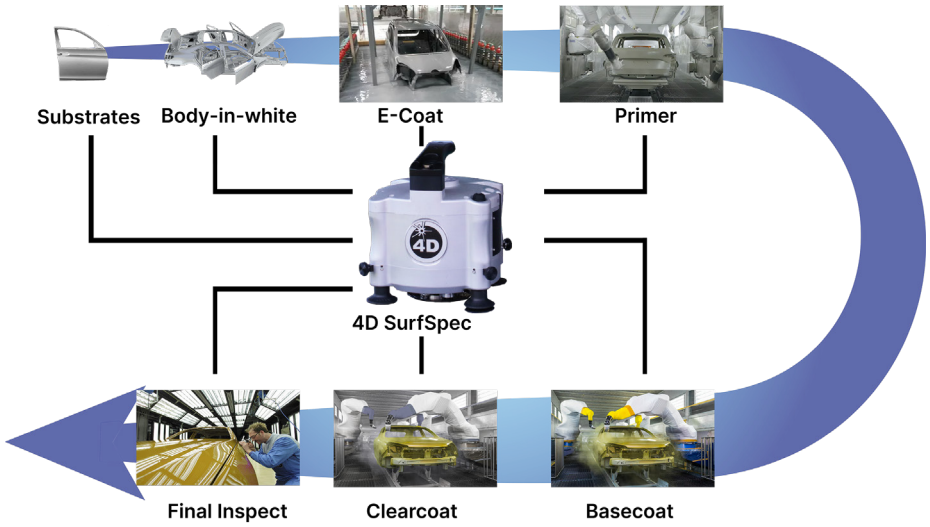


Color	% Weighted Height (µm)	Area (µm²)	Area (%)	Volume (µm³)	Feature Width (µm)	Feature Length (µm)
	-14.38	3.605E+4	0.02%	-2.480E+5	229.5	214.2

Figure 7: 3D surface measurement (upper left), identified pit (upper right), and quantification of depth, area, width, and volume of the pit (bottom)

Summary

The portable 4D SurfSpec provides 3D production measurements to quantify and correlate the surface texture of all layers of a paint system, including the raw substrates. The instrument allows fingerprinting of the entire process, with integrated analysis of the wavelength bands that differentiate good from bad surfaces. By measuring with one technology throughout the entire process, inspectors can confidently correlate the quality at each layer to the quality of the final finish. The 4D SurfSpec saves significant cost and production time by ensuring quality at each process step, and by removing unacceptable parts before further processing.



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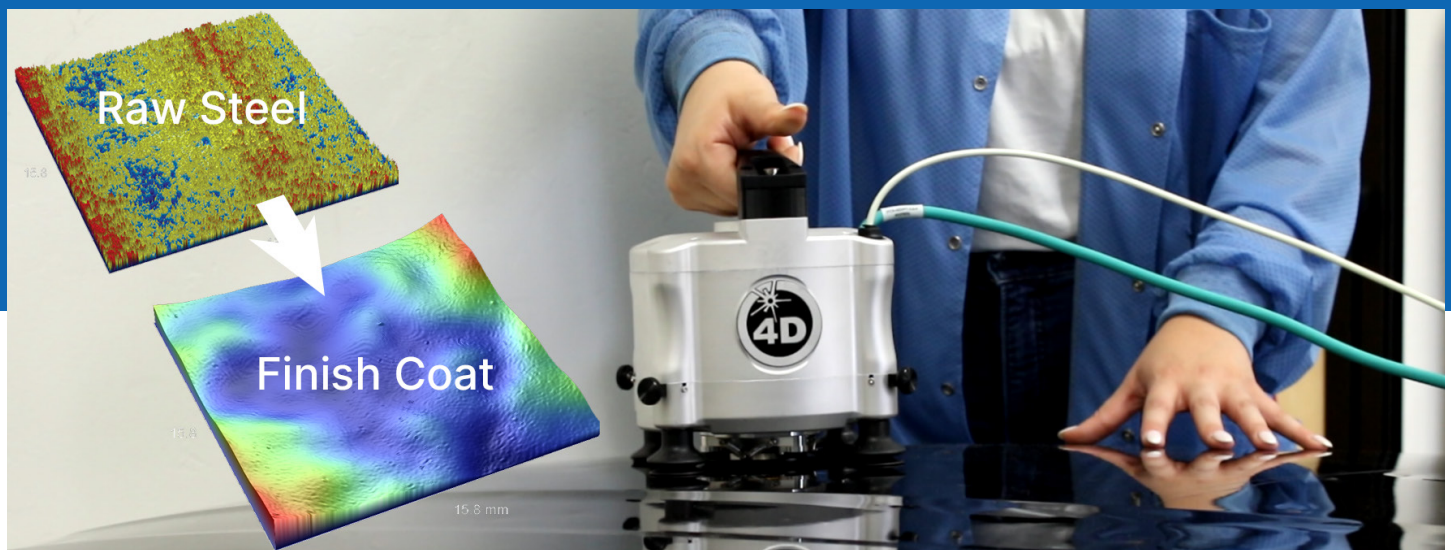
4D SurfSpec: Measure paints and coatings from bare substrate to final finish



4D SurfSpec measures rough and smooth surfaces to fingerprint paint and coating processes.

Learn more and download the datasheet:

4D SurfSpec Appearance Measurement System

The 4D SurfSpec is the only system that can measure both rough, bare substrates and smooth painted finishes. It provides feedback to correlate roughness at each layer to final finish quality. The 4D SurfSpec reduces scrap and rework by objectively quantifying appearance and surface defects. Find out more today.

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