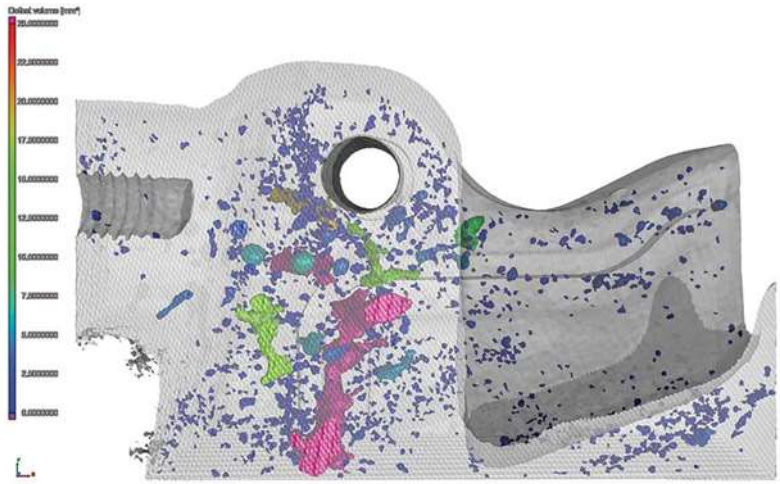
Metrology — CMM Scanning and Testing

By Eli Yudkevich

Coordinate measurement machines (CMM) are a benchmark traditionally used for measuring precision parts and tooling. The last 20 years has seen the development of a fascinating world of measurements, versatility, and high accuracy of non-contact measurement with scanners and photography using laser and X-ray technologies.



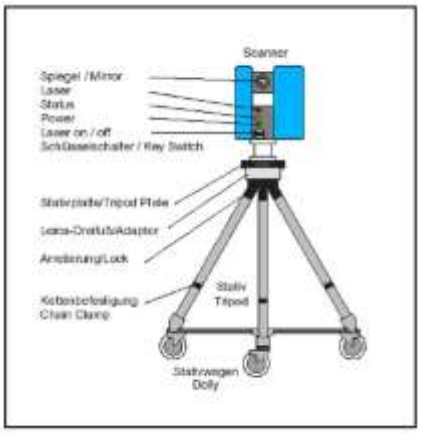
CT scanning offers a nondestructive look inside the part

For more than 50 years, the CMM has been a benchmark for precision measurements of solid objects that are machined, welded, or soldered. The CMM clearly uses a granite base plate integrated into a support structure or bridge with a vertical, arm, horizontal and a complex touch probe. The measuring technique is via the touch probe and comparisons with geometrical engineering files. In the beginning, these were two-dimensional drawings, whereas today they are CAD files that are usually hosted on a cloud. As noted, over the past two decades we have seen the arrival of a powerful "newcomer to the neighborhood" that has reached pointed capabilities and a cost value that creates a viable option to CMM technology.

3D Scanning

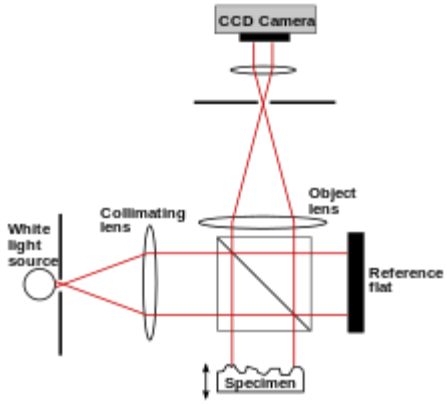
In the scanning of parts, the technology selected is that which provides the required accuracy, speed, and resolution and which meets the application being tested. When choosing the technology it is important to consider the size, color, and transparency of the object. The non-contact technology used today includes laser scanners, white light, and CT scanners.

- **Laser scanners** are mounted on an arm or on an optical device system. This allows for collecting measurements scanned from an area approximately 7m in diameter at a rate of half a million points per second.

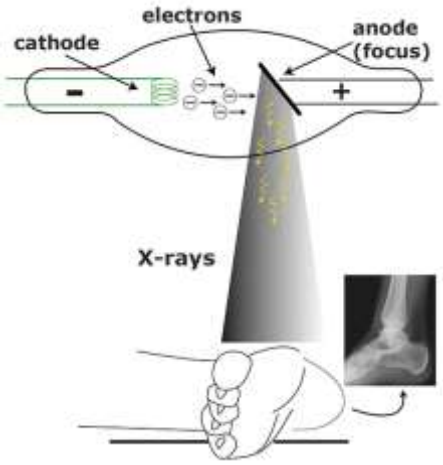


Manufactured by FARO

- **Optical scanners (white light**) mounted on a tripod catches more than a million points per second. In one scan, able to cover an area from a few square inches to a number of square meters.



- **CT scanners** enable easy measurement of the internal structure of non-ferrous assemblies by generating a point cloud from a number of two-dimensional X-ray images.



Each one of these three technologies offers high resolution of about 0.0127mm. By combining the precision of the conventional competitor CMM, the laser technology and

optical scanners enable the measurement of tiny objects or, alternatively, very large assemblies. At this stage, the measurement services available on the market include a variety of contact and non-contact technologies for ranges up to 300m.

Each of the scanning technologies also comes as a mobile unit so you can obtain measurement services from professional bodies without having to purchase and operate the equipment — each with his own considerations.

When a multi-point, accurate scan is required, a portable measuring device (portable coordinate measurement machine- PCMM) has an advantage. A PCMM 3D scan will allow for measurements in a range between 10–300m.

Advantages of 3D measurements

3D laser scanning, together with the new trend of industrial computed tomography (ICT) scanning, based on the same technology widely used in the medical world, enables a system of reading points inside and outside the product (internal and external) with a variety of manufacturing technologies. 3D scanners are used for testing metal parts, composite parts, thermoplastic parts, elastomers, wood, fiber materials and fabrics. CT scans allow for the internal measuring of thick aluminum castings, plastic parts and rubber injections, prepared foods, packaging, archaeological findings and works of art. There is an old joke which says that with the help of a CT scanner we could have known about Venus de Milo's arm problem long before she lost her arm.

CT scanners can detect porosity issues, proportional changes, analytical failure, fiber volume and direction, leaving the part intact with no damage. In direct contrast to CMM techniques, laser and CT scans map the test surface and capture all points simultaneously, even in complex, hard-to-reach areas, For example, when a typical touch probe captures 300 points for comparing with the CAD, the laser and CT scanners will capture millions of points. A typical system today offers measuring accuracy of 60–100 microns in a 4m range (ref. VDI2630) .

The Major Advantages of Laser Scanning

There are a number of advantages for using laser scanning over CMM and more basic tools.

- Coverage of measured area
- Speed of measuring
- Measurement Atomization
- Simplification of operation
- Price
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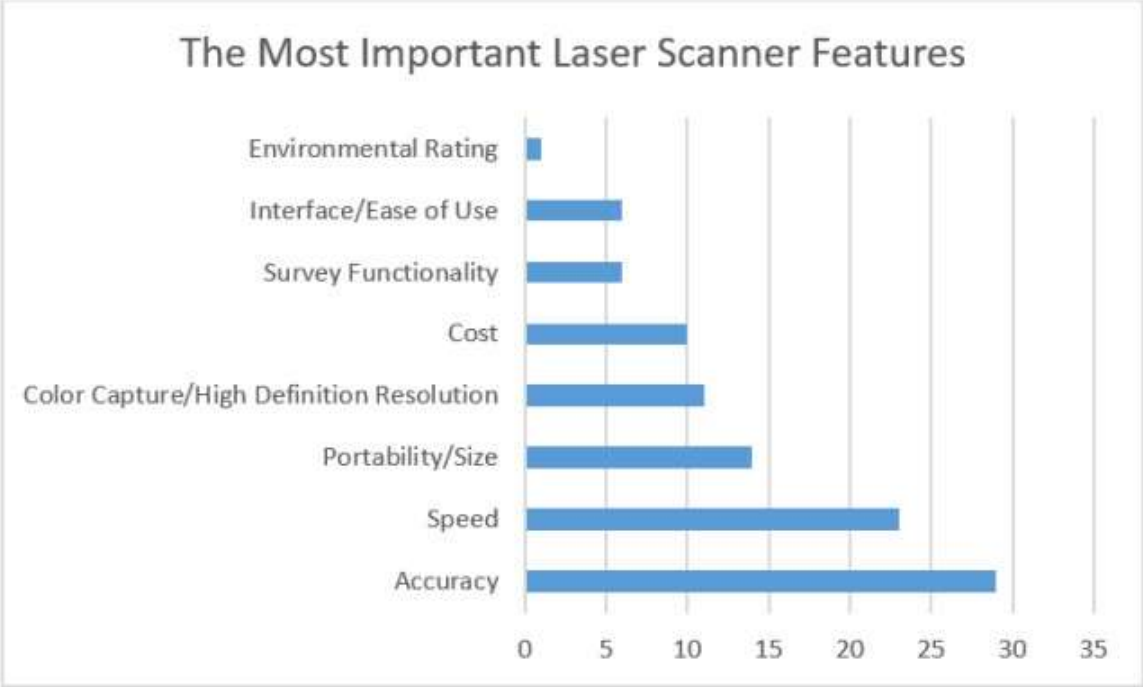


Advantages of CT Scanners

In addition to providing a solution for 3D images inside the smooth cavity, there is also the advantage that CT is the only way to obtain data for actual dimensions without the need to destroy or contact. If there is a need for 3D inertia relief analysis or analysis of porosity, material structure or assembly inspection, the CT scan (industrial X-ray) is the only existing and worthy process.

MetraSCAN 3D Scanner
(image courtesy of Creaform)

For every object including castings, it is possible to get a 3D image in 360° during the X-ray process when maximum reading points are captured from every angle. When the CT scale becomes a points cloud, a CAD can be generated for the object being scanned. This is something that leads to significant savings during the manufacturing of the first part relative to the amount of time required for CMM. Sophisticated 3D software that comes with the scanner allows you to generate first part reports, statistical reports, and 3D computer models for visualization and for analysis programs. In the end, it is possible to verify that for each part that has been inspected, there are no structural problems such as cracks before or after the machining process.

Categories and Types of Laser Scanners

Scanners can be classified into two main categories based on the method of capturing information:

- White-light and structured light scanners take a single snapshot of the object.
- Arm scanning portable devices capture information continuously

White-light scanner in a lightweight structure: Examples: Creaform MetraSCAN 3D scanner, Hexagon's Leica Absolute Scanner (LAS) is positioned via an external optical tracking device that uses passive / active targets that allow it to position itself within the system of coordinates.

The Leica Absolute Scanner LAS-20-8 (pictured right) offers high accuracy as well as freedom of movement, but requires direct eye contact with the Tracker. The price is generally more expensive than other handheld 3D scanners.

The Faro® Cobalt Array Imager uses one or more cameras that position themselves via part geometry. When the distinct camera requires the projector's position to be fixed in advance

relative to it, when two cameras are used they must be calibrated together.

The advantage of this method is good resolution, but on the other hand it is requires multiple scans to be performed in order to cover all the angles of complex parts, something which prolongs the process.

Hexagon's Romer Absolute Arm (below) can be positioned via mechanical encoders inside the arm. Its main advantage is the duality of the arm for both scanning and contact testing. On the other hand, since the arm needs to be fixed to a stable surface, it tends to be susceptible to vibrations and other environmental factors. The mechanical connection between the fixation and the scanner causes the arm to be ineffective for scanning difficult to access areas.

Creaform's handheld 3D HandySCAN scanner (right) is positioned independently in real time using targets, object geometry or both. This combination is called "hybrid positioning". Two of the scanner's cameras generate a stereoscopic image (a technique used for creating the illusion of depth) and allows the device to identify the location of the scanner relative to a specific point on the object.

The main advantage of the handheld scanner is its ease of transmission and use, at a reading rate of half a million points per second. Some of these scanners can reconstruct and rebuild the triangular mesh during the scanning process.

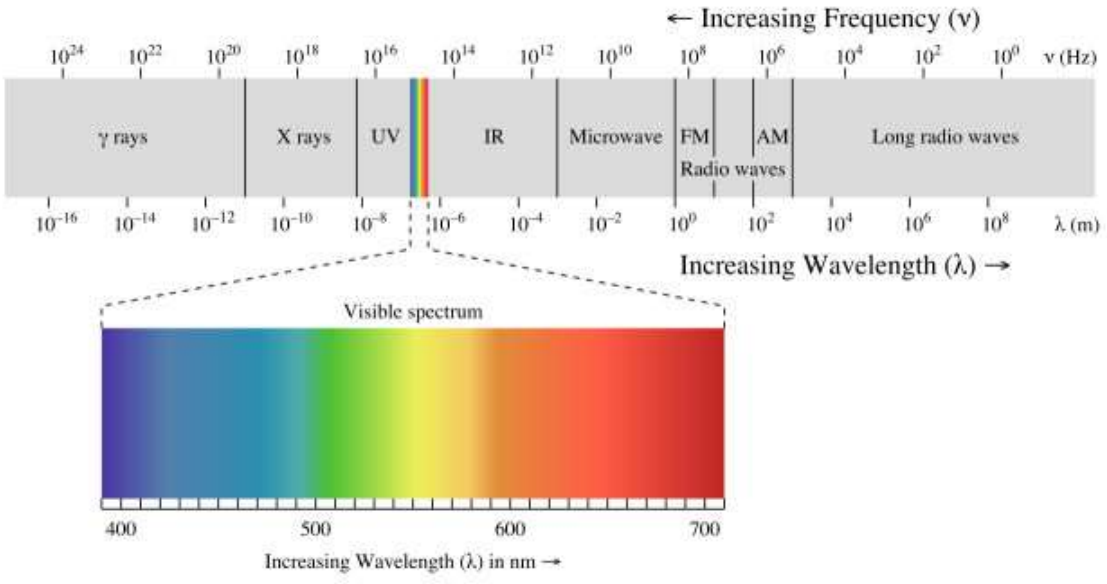
Unfortunately, these scanners are found lacking when it comes to scanning volume (as volume increases so does error). This can be compensated by photogrammetry (making measurements from photographs) for target location, although it extends installation time and limits scan volume.

Comparison Table of 3D Scanning Methods

	Single Snapshots or Scans		Continuous Image Capture	
Scanner Category	White-Light and Structured-Light Systems		Scan Arms and Portable Handheld Scanners	
Scanner Type	Tracked Scanners	Structured-Light Scanners	Scan Arms	Portable Scanners
Positioning	External Optical Tracking Device	Offline Target and Geometry	Mechanical Encoder	Real-time Targets, Geometry or Both
Advantages	• Good accuracy • Excellent precision • Freedom of movement	• Excellent resolution	• Accommodates scanners and touch probes	• Easy to transport and use
Limitations	• Tracker requires direct line of sight to scanner • Expensive	• Multiple scans required to cover all angles	• Sensitive to environmental factors • Lack of flexibility	• Errors increase as scanning volume grows

The Significance of Color in Laser Scanners

It is "sexy" to sort laser scanners in terms of their laser color – typical red, blue or green, but this may be a mistake. The story of colors is more of a marketing hype. The general

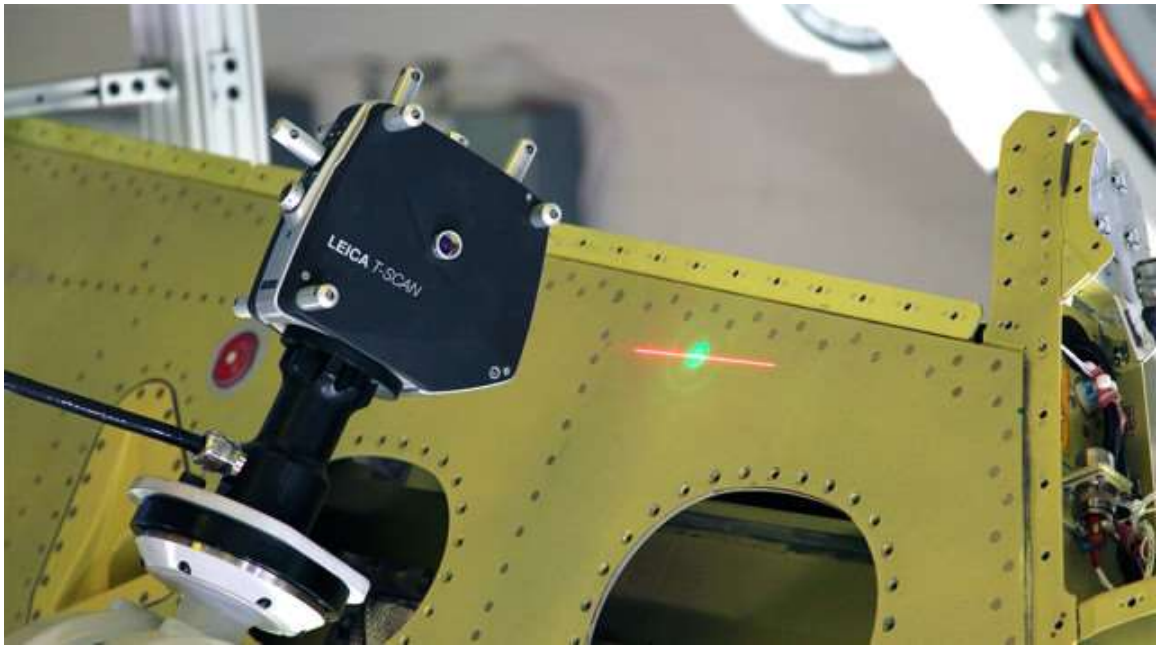


rule, in fact, depends on the image processing and filter used for it. Good results can be obtained from any color.

In the electromagnetic spectrum, visible light will be in the range of 400-700 nm. Thus, the maximum difference between two different laser colors (blue and red) is about 300 nm. This is an order of magnitude smaller than today's tolerance in today's world of manufacturing. So when it comes to laser color, choose your favorite color.

Laser Scanning for Aerospace Applications

The aerospace industry, especially the world of production, boasts far tighter tolerances than those in other industries. The question asked is whether laser scanners can offer the accuracy that is required. Or, is CMM consistently the preferred option? It is clear to us that when pointed accuracy is required, CMM is definitely the way to measure.



The common assumption is that laser scanners can be used to measure internal parts of airplanes because the tolerances there are much more open. When it comes to the outer shell, the structure and engine parts in particular, the tight tolerances, in some cases, do not conform to laser scanner performance (where the options are under 10 microns). It is clear beyond a doubt that the laser scanners and CMMs are not techniques that compete with each other at this stage. There are also ways to combine both techniques in order to save time.

The Main Conclusion

Use the appropriate technology or a combination of technologies in accordance with your customer's requirements for the product, be especially careful in places you measure holes for placement and diameter. At this point, the scanner has not replaced the CMM — which is still alive and kicking.

Good luck!

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