

VideoProbe* 3D Measurement Handbook

A guide to advanced 3D measurement technologies, techniques and applications for video borescopes used in remote visual inspection applications.



Get the most from your Mentor Visual IQ*!

(Applies to Mentor Visual IQ software version 2.5 or later)

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Introduction

Advances in image based 3D measurement are making the video borescope an increasingly powerful tool in the inspector's toolbox. While in the past, inspectors could identify indications and capture images; today's advanced video borescopes allow them to map, measure, and analyze indications in 3D and to share images and data wirelessly with remote experts. With enhanced precision and accuracy, this new functionality is allowing video inspection to complement, or in some cases, replace other NDT modalities.

This guide is designed to help inspectors and asset owners understand measurement technologies available on the Mentor Visual iQ and how they can be properly applied to improve decision making in remote visual inspection applications.

Many video borescope owners underutilize the advanced features of their inspection equipment due to a lack of training. Using this handbook as a guide, you can learn to apply new techniques, and make your expertise a competitive advantage for your organization.

The Importance of Accurate Measurement

Remote visual inspection is frequently used to determine the serviceability of an asset. That determination is often based on the measurement of an indication or feature inside the asset. Inaccurate measurements can result in unnecessary downtime, scrap, and maintenance costs as well as safety or reliability risks. It is therefore critical that inspectors understand how to properly apply available measurement capabilities to maximize the quality of decision making.

With traditional measurement technologies, such as stereo, shadow, or comparison, the inspector has little ability to assess either the quality of the data used to compute the measurement result or the correctness of the cursor placement for the desired measurement. This can often lead to inaccurate measurements and potentially to costly incorrect decisions.

The latest 3D measurement technologies allow the real-time use of a 3D XYZ point cloud to check data quality and cursor placement accuracy from multiple angles and perspectives. This gives inspectors an unprecedented ability to check their work and avoid costly mistakes.

Accurate VideoProbe measurement requires:

- A well-trained operator
- Properly calibrated and maintained equipment
- Choosing the correct measurement technology for the application
- Correct measurement tip positioning and measurement setup
- Analysis of data quality and cursor-placement accuracy

Enabling Technology and Connectivity

When critical assets depend on accurate measurement, it may be time for a second opinion. For the first time, live video inspections can now be viewed in real time from a PC, tablet or smartphone across the room or around the world. The InspectionWorks Connect remote collaboration tool allows two-way collaboration and image annotation with field inspectors in real time using Wi-Fi or Ethernet connectivity.

By putting extra eyes on inspections, you'll benefit from greater expertise, improved probability of detection, better inspection productivity and reduced costs. InspectionWorks Connect is available as an option on all models of Mentor Visual iQ.



Measurement Technologies

(see Mentor Visual iQ Manual – Advantages of Measurement Types)

3D Phase Measurement

Using patented structured-light technology, 3D Phase Measurement enables inspectors to locate, measure and analyze an indication using the same tip optic. The wide field of view and large depth of field allow for measuring with the same tips used for inspecting, thus eliminating the extra steps required to back out, change the tip and then relocate the indication.

In effect, 3D Phase Measurement provides accurate measurement “on-demand” while saving time and increasing overall inspection productivity. 3D Phase Measurement employs structured light patterns projected from the tip to create a 3D surface scan of the viewing area and can measure all aspects of surface indications.

Benefits:

- View and manipulate a 3D point cloud for detailed assessment of surface shape and measurement correctness
- Full-screen viewing of measurement image for greater resolution
- Navigate, inspect and measure without changing probes or tip optics
- Available on 6.1 mm diameter probes

3D Stereo Measurement

Introduced in 2015, 3D Stereo Measurement is GE’s newest video borescope measurement technology. 3D Stereo Measurement utilizes the same optical tips as traditional Stereo Measurement but employs more advanced calibration and processing algorithms to generate a full 3D point cloud representation of the target surface that can be viewed, manipulated, and analyzed.

Benefits:

- More accurate, repeatable measurement compared to traditional, outdated stereo or shadow measurement
- Provides better matching capabilities than Stereo Measurement on horizontal and repeating indications
- View the camera image and 3D point cloud side-by-side for highly efficient measurement analysis
- Measure effectively on shiny (or highly-reflective) surfaces which include detail
- Measure on surfaces with some minor movement present
- Available on 4.0, 6.1 and 8.4 mm probe diameters

Stereo Measurement

Traditional stereo measurement, which, like 3D Stereo, utilizes a patented prism to obtain left and right stereo images from slightly different perspectives. The matching of surface points in the left and right images at the cursor locations allows 3D coordinates and measurement results to be computed. This technology, available for more than a decade, is useful on systems with limited computing power but does not provide a 3D point cloud and therefore limits the inspector’s ability to assess measurement quality.

Comparison Measurement

A more traditional 2D measurement technology that uses a physical reference target placed by the manufacturer or inspector at the same tip to target distance as the indication.

PC Re-Measurement

Using software such as Inspection Manager to conduct post-inspection image measurement and analysis on a stored image. Today re-measurement capabilities are also available on-device using the Mentor Visual iQ system or on PC.

3D MEASUREMENT BEST PRACTICES: TECHNIQUES AND TIPS

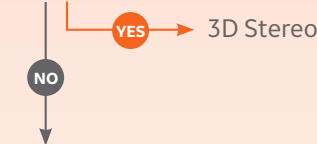
These best practices apply to both 3D Phase Measurement and 3D Stereo Measurement. Use this best practice guide to provide the best results when setting up measurement with your VideoProbe. Additional guidelines for specific measurement types are listed on page 6.

General Guidelines

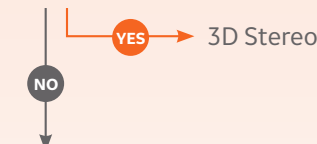
- Ensure the inspector is trained and qualified to perform measurement.
- Use in-house procedures or the selector tool on this page to choose the appropriate measurement technology and type for your application.
- Ensure that your measurement tip and probe optics are clean and that the tip is securely attached. If using a stereo tip, be sure to correctly identify the tip serial number when first entering measurement. 3D Phase Measurement tips are automatically recognized by the system.
- Verify that the system measures accurately with the GE-supplied NIST traceable verification block before and after performing measurements.
- Position the tip as close as possible to the measurement area (low MTD value). Stereo and 3D Stereo require the image to be in focus, but with 3D Phase Measurement, small depth measurements (< 0.010") are generally most accurate when close enough for the image to be somewhat out of focus. Measuring from too far away is the most common cause of inaccurate measurements.
- Pay attention to warnings displayed by the system during measurement, which may signal improper setup or inappropriate MTD for the measurement performed.
- Check the measurement setup and cursor placement with 3D point cloud view. Many issues are difficult to recognize using the 2D image alone but are obvious in the 3D point cloud.
- When performing small depth or depth profile measurements, use the 3D point cloud view with depth map enabled to verify that the indication clearly stands out from the data noise. If not, capture another image from a closer distance or different orientation.
- When measuring the depth of a feature such as a pit or dent, use the point cloud view to verify that you are measuring at its deepest point and that the measurement reference plane is accurately aligned with the reference surface.
- With 3D Phase Measurement, reflections or shadowing can create regions of lower-quality data, which are highlighted in yellow. Avoid measuring in these areas whenever possible, especially for depth or depth profile measurements. Performing another capture from a different orientation may eliminate the yellow regions.
- Areas where the system was unable to determine 3D coordinates are highlighted in red. Measurements cannot be taken in these red areas.

Choose the Right 3D Measurement Technology

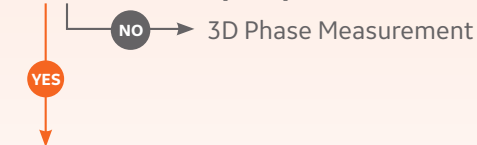
Is a 4 mm or 8.4 mm probe required?



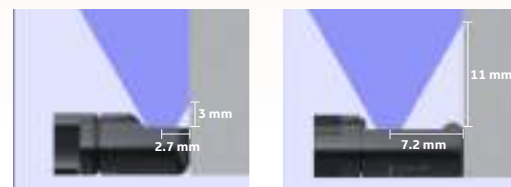
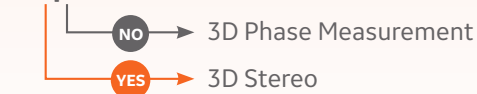
Are you measuring on highly-reflective, oily, or wet surfaces?



Is a side-view tip required?



Do the viewing optics need to be very close to the end of the side-view tip to see into the inspection area due to mechanical obstructions?



3D Stereo Side View

3D Phase Side View

- For best data quality, keep the probe as still as possible during image capture. This is particularly important with 3D Phase Measurement due to the large number of images captured.
- With 3D Stereo, adjust image brightness and viewing orientation to minimize glare in the area of interest prior to capturing a measurement image.
- Straight lines or edges on viewed objects often appear curved in the 2D image due to the viewing perspective and optical distortion. As all measurements are performed in 3D, the straight 3D measurement lines are drawn on the 2D image as they would be seen by the camera, which is often curved. This helps with alignment to straight edges and more accurately indicates measurement location.

Choose the Right Measurement Type For Your Application

While multiple measurement types may be used for certain applications, this chart is intended to show the expert recommendation.



Length

- Simple measurement of features or components
- Length of cracking
- Component size migration through expansion or erosion/corrosion/wear
- Remaining size of wear indicators
- Location/zone of indications on a part



Area

- Blade corners
- Coating loss
- Surface area of pitting or corrosion
- Area of FOD impact



Point to Line

- Turbine blade edge damage
- Gap width
- Weld width
- Missing blade corners



Multi-Segment

- Total travel path of a crack
- Blade edge blending or indication entry angle
- More accurate than a length measurement on curved or irregular surfaces



Depth

- Blade tip to shroud gaps
- Pits or dents from corrosion, erosion, or FOD impact
- Pipe inside diameter
- Weld height
- Stator vane rock
- Gap width



Depth Profile

- Depth of isolated corrosion or erosion pits
- Depth of FOD impact damage
- Weld height or wear groove depth
- Quick assessment of surface contours



Area Depth Profile

- Corrosion, erosion and pitting
- FOD impact damage
- Maximum weld height
- Maximum wear groove depth



Measurement Plane

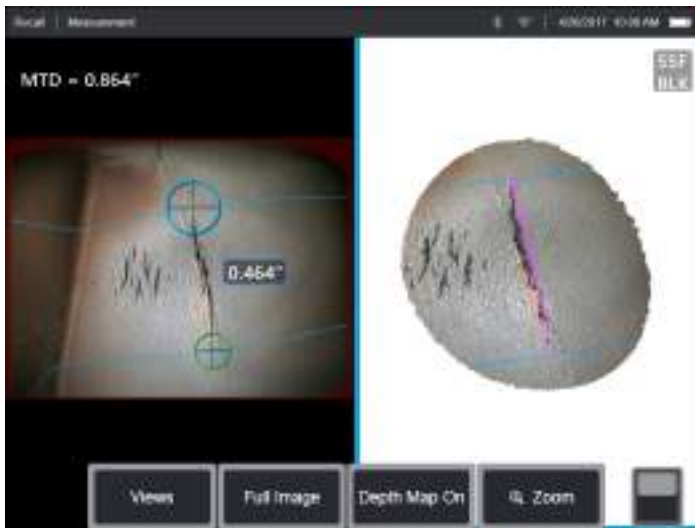
- With Area for missing corners
- With Point to Line for blade edge damage
- With Depth for blade tip to shroud gaps
- With Length or Point to Line for small features
- With Area Depth Profile when measuring in a field of pits

MEASUREMENT TYPES



This section will detail each of the measurement types available on the Mentor Visual iQ videoprobe, suggest applications where each technique can be most effective, and provide tips and suggestions for accurate measurement setup.

Length



Measures the straight-line distance between two selected cursor points.

Example Applications:

- Simple measurement of features or components
- Indication length measurement (i.e., cracks)
- Measurement of component size migration through expansion or erosion/corrosion/wear
- Determining the remaining size of wear indicators
- Measuring location/zone of indications on a part

3D Surface Mask:

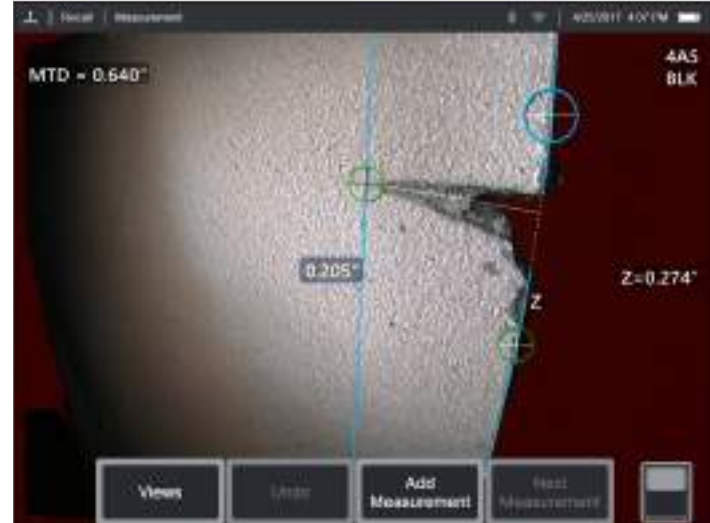
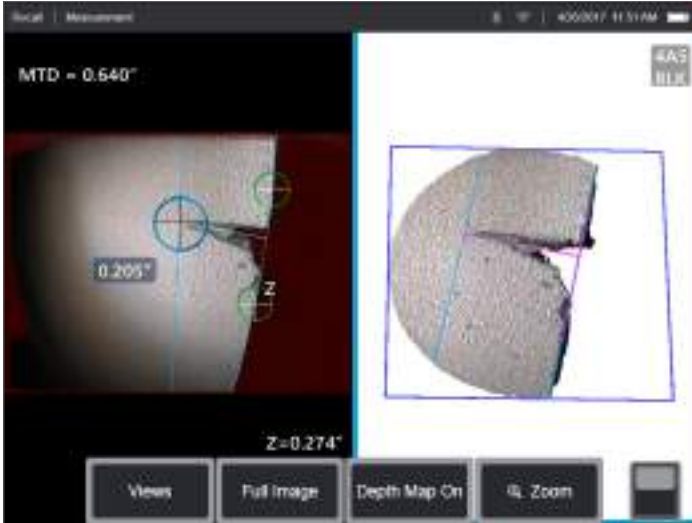
When enabled in Settings, a blue mask will highlight surface points where planes perpendicular to the straight 3D line between the cursor points intersect the viewed surface.

Best Practices to Improve Measurement Accuracy:

- Length is a straight-line measurement. It is not suitable to measure the distance across a curved surface.
- When measuring a distance from an edge, adjust the cursor positions such that the light blue 3D Surface Mask appears along the edge rather than at an angle to the edge. This will minimize error caused by measuring diagonally. Point to Line may also be a better option in such cases.
- Review the 3D point cloud to ensure your cursors are located correctly. Diagonal or off-angle measurements will induce error.
- Move the tip closer to make the target area as large on the screen as possible, while keeping the cursor point areas in focus.
- Watch for orange advisory indicators to ensure the measurement distance is within the confidence interval.
- In both 3D Phase and 3D Stereo measurement it is important to start with a crisp image so that the cursors can be placed accurately on the indication.
- Use a Measurement Plane when red areas prevent proper cursor placement or 3D noise may be affecting the result. See the Measurement Plane section for details.



Point to Line



Measures the perpendicular distance between a line (defined by two points), and a selected point.

Example Applications:

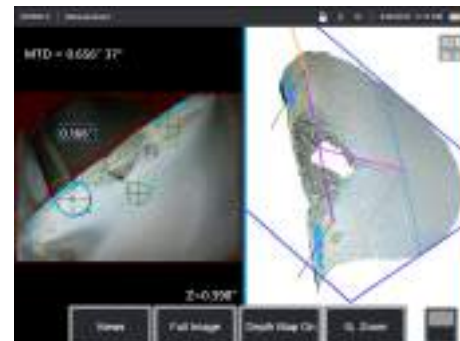
- Turbine blade edge damage
- Estimate missing corner area using multiple point-to-line measurements
- Gap or groove width
- Weld width

3D Surface Mask:

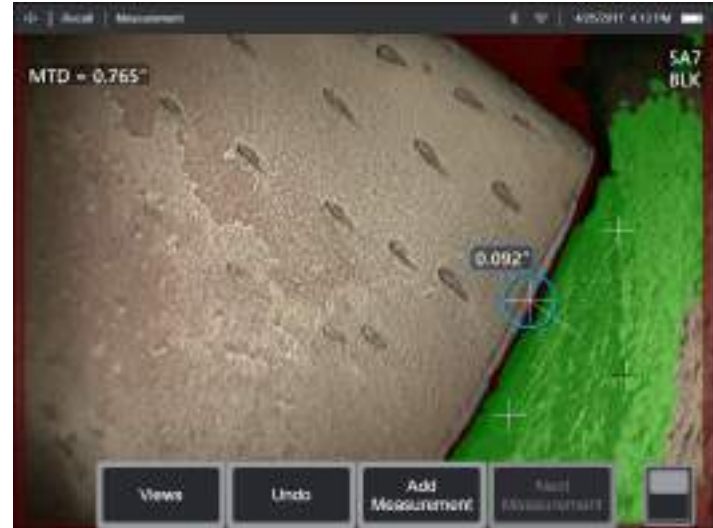
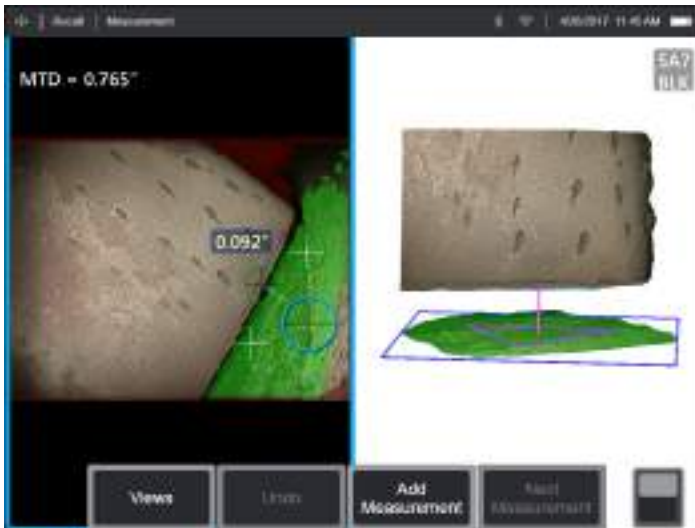
When enabled in Settings, a blue mask will highlight surface points where planes perpendicular to the straight 3D line between the third cursor point and the reference line intersect the viewed surface.

Best Practices to Improve Measurement Accuracy:

- Review the 3D point cloud to ensure your cursors are located correctly.
- Space the first two cursors far apart along the reference edge. If possible, place them on opposite sides of the indication being measured. Placing them close together can cause error by tilting the reference line in 3D space.
- Check the point cloud to verify that the reference line is not tilted with respect to the reference edge on the part. This is especially important when both reference line cursors are on the same side of and away from the third cursor.
- Also check the point cloud to be sure the measured distance is not at a diagonal, which can give a higher-than-actual result.
- Use a Measurement Plane when red areas prevent proper cursor placement or 3D noise may be affecting the result. See the Measurement Plane section for details.
- Use a Measurement Plane when measuring distance from a rounded edge to determine the perpendicular distance from the edge. Position the reference cursors such that the light blue 3D Surface Mask appears along the outer face of the rounded edge.



Depth



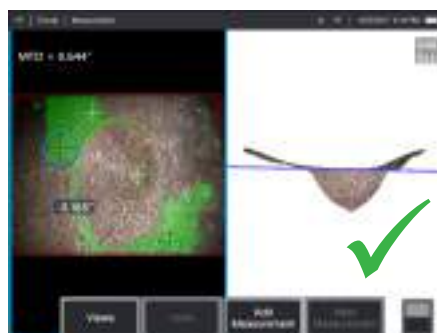
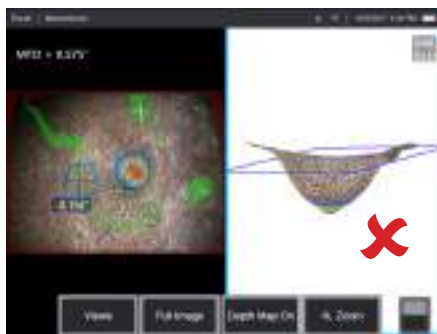
Measures the distance from a reference plane (defined by three selected points) to a fourth selected point above or below the plane.

Example Applications:

- Blade tip to shroud gaps
- Pits or dents from corrosion, erosion, or FOD impact
- Pipe inside diameter
- Weld height
- Stator vane rock
- Gap width

Best Practices to Improve Measurement Accuracy:

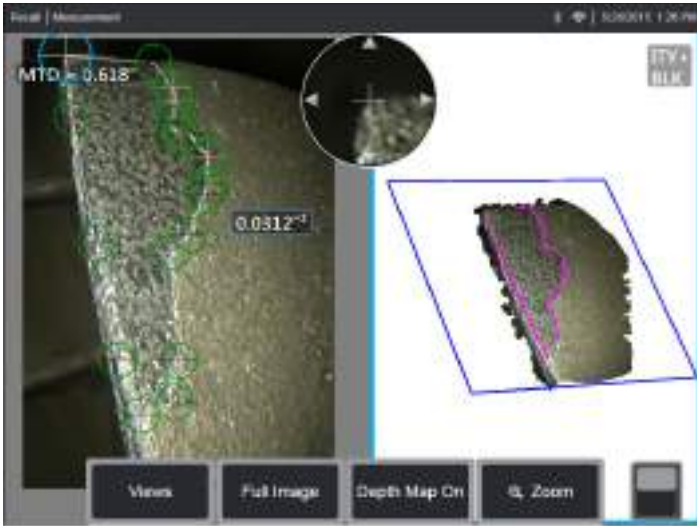
- The measurement tip should be as close as possible to the indication to increase the accuracy of measurement.
- When using 3D Phase Measurement, off-perpendicular views yield the best results for depth measurements, especially when measuring objects with shiny surfaces.
- Position the three reference-plane cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface. If measuring a recessed point, use the color gradient to ensure that the measurement is taken at the deepest point. If measuring height or depth to a flat surface, try to maximize the amount of light blue shown on that surface.
- Check the 3D point cloud view to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- The green Surface Mask visible when a reference plane cursor is active indicates points very close to the reference plane. Adjust the cursor positions to maximize the amount of green on the reference surface. The 3D point cloud view can also be used to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- After the third cursor is placed, the Depth Assist feature will often automatically place the fourth cursor at the deepest point, highest point, or on a blade edge nearby. Check the position of the auto-placed cursor and adjust if necessary.
- Enable depth map mode in the point cloud view to better see surface contours and ensure that you are measuring the desired point—often the highest or lowest on an indication—and that the indication clearly stands out from the 3D data noise.
- The line projected from the depth measurement point should end near or within the triangle formed by the reference-plane cursors to minimize inaccuracy due to plane tilt.
- If you must measure at a point far outside the reference triangle, increase the size of your reference triangle to compensate (this only applies to flat surfaces, not curved surfaces).
- Use a Measurement Plane when measuring blade tip to shroud clearance and red areas along the blade edge prevent proper fourth cursor placement or 3D noise may be affecting the result. See the Measurement Plane section for details.



3D Surface Mask:

When enabled in Settings, surface points very close to the reference plane are shown in green. Surface points the same distance from the reference plane as the measurement result are shown in light blue. If the result is negative, a color gradient also highlights regions deeper than the measurement point with red indicating the deepest points.

Area



Measures a planar area on a surface by outlining an indication with multiple cursor points.

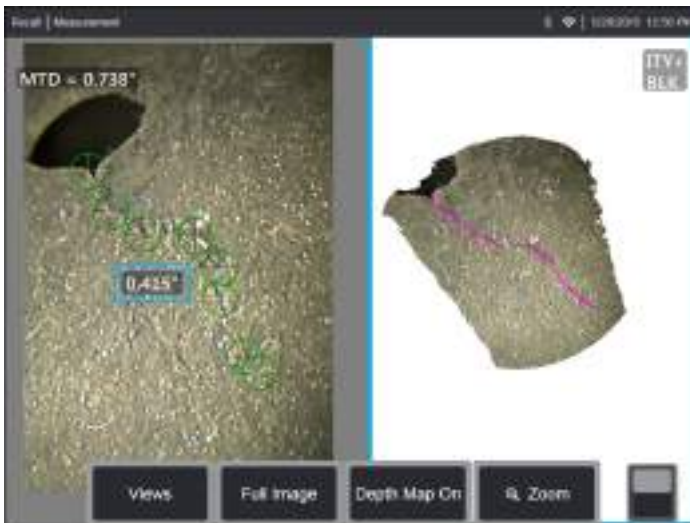
Example Applications:

- Missing blade corners using a Measurement Plane
- Coating loss
- Surface area of pitting or corrosion
- FOD impact damage

Best Practices to Improve Measurement Accuracy:

- Check the point cloud to ensure accurate cursor placement.
- When measuring a curved surface, reduce error by measuring multiple smaller areas and combining the results.
- Use with a Measurement Plane to measure area and lengths of blade missing corners. See Measurement Plane section for details.

Multi-segment



Measures the total length along a curved or jagged path using multiple cursors placed along the path of the indication. When three cursors are used, it also provides the 3D angle between the line segments.

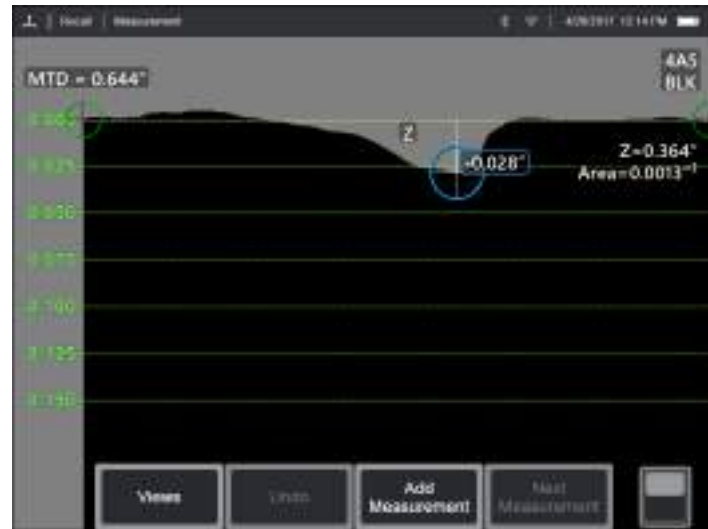
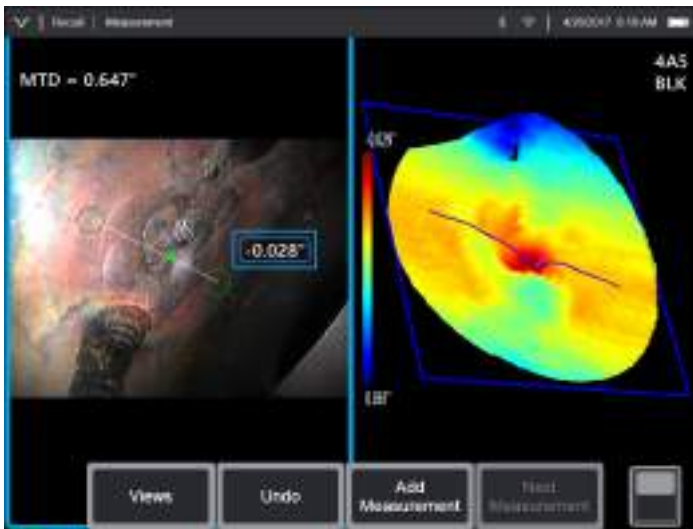
Example Applications:

- Total travel path of a complex crack
- Total length along a curved surface
- Use three cursors to measure the angle between a turbine blade edge and an indication or blended area

Best Practices to Improve Measurement Accuracy:

- Check the point cloud to ensure accurate cursor placement.
- Space your cursors as far apart as possible while following the path of the indication to minimize the effect of 3D data noise on the result.
- If measuring an angle (only provided with three cursor Multi-segment) along an edge, accuracy may be improved by using a Measurement Plane.

Depth Profile



From any viewing angle, maps the perpendicular distance from a reference plane along a line between two selected points and automatically identifies the deepest or highest point.

Example Applications:

- Depth of isolated corrosion or erosion pits
- Depth of FOD impact damage
- Weld height or wear groove depth
- Quick assessment of surface contours



3D Surface Mask:

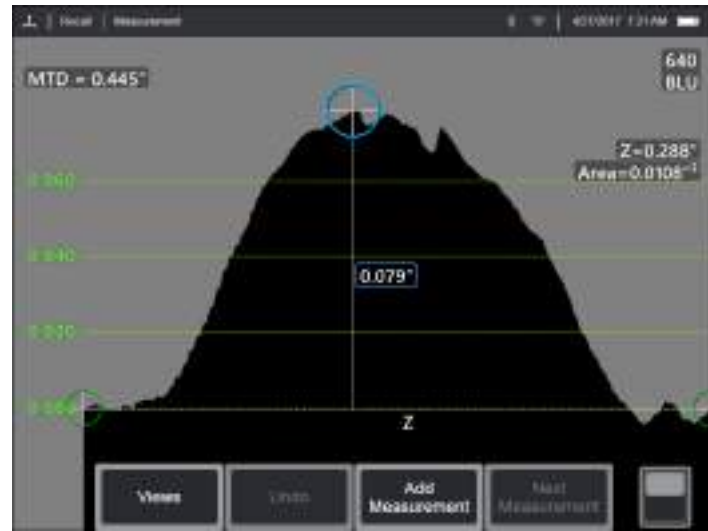
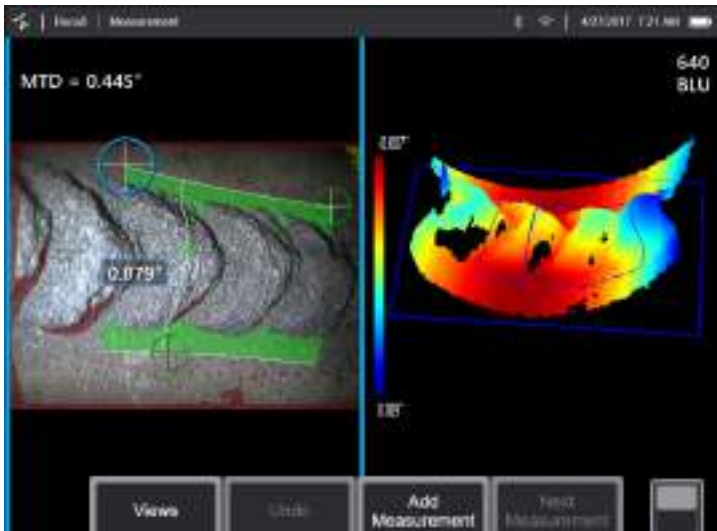
When enabled in Settings, surface points very close to the reference plane are shown in green. Surface points the same distance from the reference plane as the measurement result are shown in light blue. If the result is negative, a color gradient also highlights regions deeper than the measurement point with red indicating the deepest points.

Best Practices to Improve Measurement Accuracy:

- Position the measurement tip as close as possible to the indication to increase measurement accuracy.
- Position the cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface. If measuring a recessed point, use the color gradient to ensure that the measurement is taken at the deepest point. If measuring height or depth to a flat surface, try to maximize the amount of light blue shown on that surface.
- Enable depth map mode in the point cloud view to better see surface contours and ensure that you are measuring the desired point—often the highest or lowest on an indication—and that the indication clearly stands out from the 3D data noise.
- The green Surface Mask visible when a cursor is moved indicates points very close to the reference plane. Adjust the cursor positions to maximize the amount of green on the reference surface. The 3D point cloud view can also be used to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- If the cursor turns red, this indicates improper placement.
- As the reference plane is determined by fitting to all the surface data within both cursor perimeters, ensure that the two cursors are fully positioned on the same plane of interest—not overlapping an edge, or on offset or curved surfaces that could cause measurement error.
- If measuring on a curved surface, such as inside a small pipe, space the cursors apart in a direction parallel to the curvature to keep them on the same plane. In the point cloud view, the blue reference-plane square should appear tangent to the reference surface.
- The Depth Profile view may be used to help visualize the surface contours along the profile slice.
- In applications seeking the deepest or highest point, Area Depth Profile or Depth may be preferred over Depth Profile as they automatically identify the deepest or highest point in an area.



Area Depth Profile



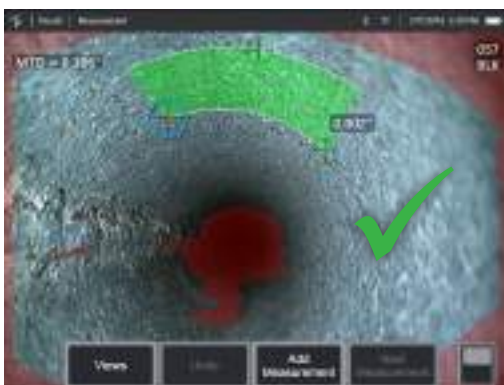
Sweeps a series of depth profile slices over an area defined by three cursors and identifies the profile slice having the highest or lowest point.

Example Applications:

- Corrosion, erosion and pitting
- FOD impact damage
- Maximum weld height including orbital welds
- Maximum wear groove depth

Best Practices to Improve Measurement Accuracy:

- Position the measurement tip as close as possible to the indication.
- Use with reference surfaces that are flat or have curvature in only one direction, such as a straight section of a pipe. Do not use on surfaces with complex curvatures such as a pipe elbow or turbine blade root at the leading or trailing edge.
- When measuring on a curved surface, position the cursors such that the reference profile lines are curved. If unsure of proper orientation, practice on a test piece of the same shape. When cursors are properly placed, you should get a result close to zero, and most of the area should be shown in green. See images below.
- If only a small line of 3D Surface Mask green is shown near the two reference profile lines, the cursors are likely positioned incorrectly on a curved surface.
- The green Surface Mask visible when moving the cursors indicates points very close to the reference planes of the depth profile slices. If you only have a small line of green near the two reference profile lines, you are likely positioning the lines incorrectly on a curved surface. See images below.
- The reference profile lines follow the surface curvature and are used to determine the reference planes for the profile slices. Position the cursors such that the reference profile lines are fully on the reference surface.
- Use the 3D point cloud to verify that the reference plane for the result slice, indicated by a blue square, is accurately aligned with the reference surface at the location of the result slice.
- The first two cursors define the first reference profile line. The third cursor sets the distance between the second reference profile line and the first. The system determines the endpoints of the second reference profile line to match the curvature of the surface along the first. If you have difficulty getting the second reference profile line where you want it, you are likely not setting up the measurement correctly with respect to surface curvature.
- The Depth Profile view may be used to help visualize the surface contours along the identified profile slice.

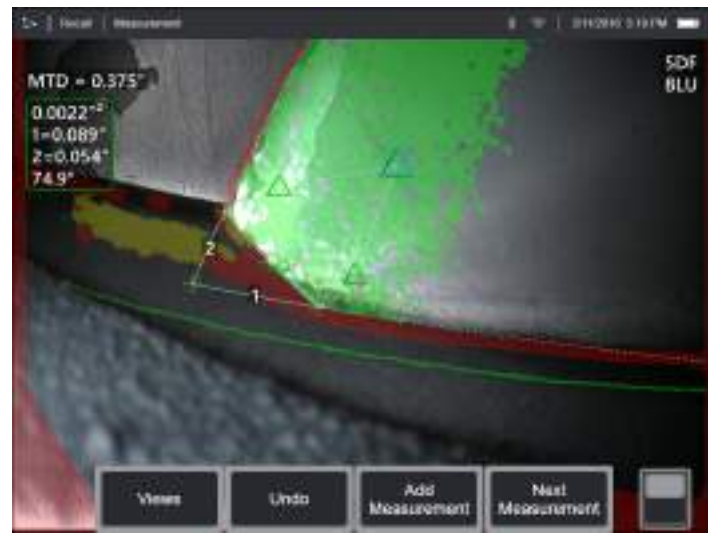
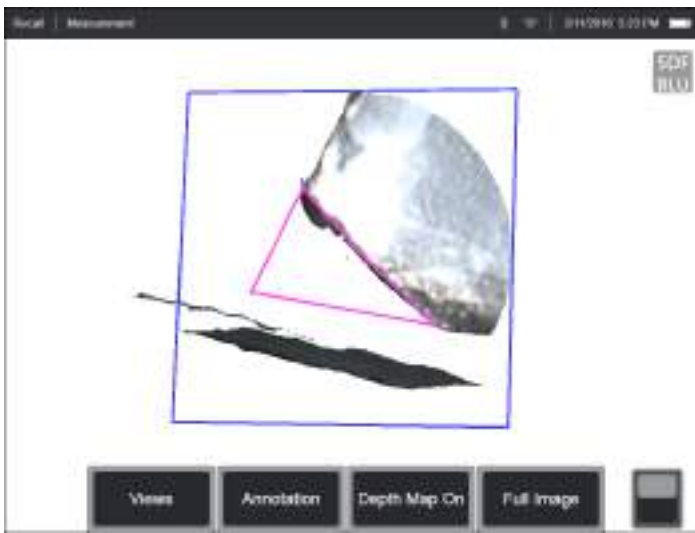


3D Surface Mask:

Each depth profile slice in the series uses a reference plane determined from the surface orientation at the slice endpoints. This allows curved surfaces, such as pipe walls to be followed. When enabled in Settings, the 3D Surface Mask shows surface points near the individual slice reference planes in green.



Measurement Plane



Measurement aid used in conjunction with other measurement types to allow the placement of cursors in red areas where no 3D data is present or where noise in the 3D data may be reducing measurement accuracy.

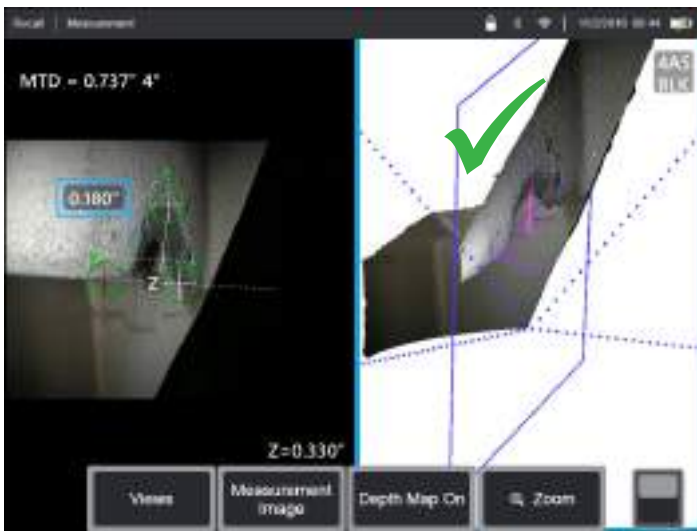
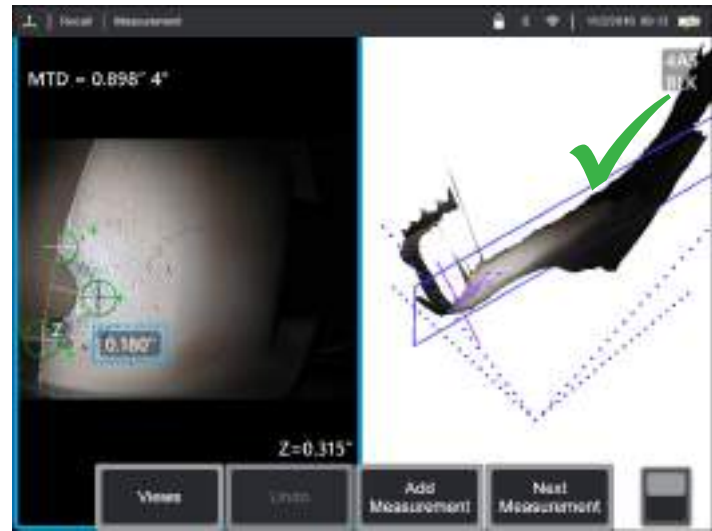
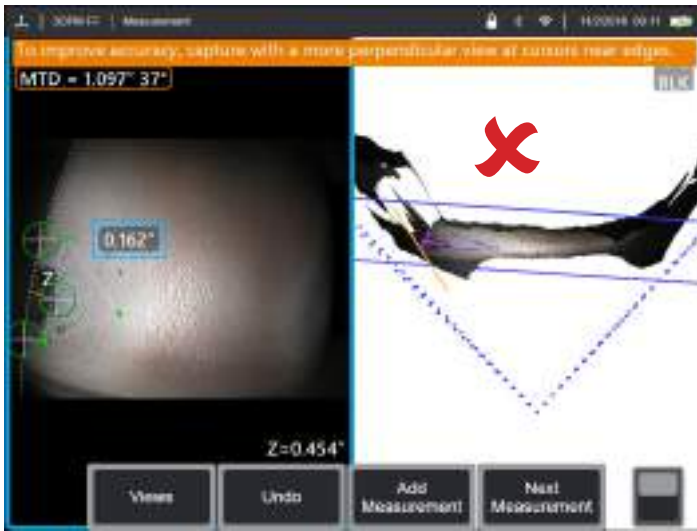
Example Applications:

- With Area to measure missing corners
- With Point to Line for blade edge damage
- With Depth for blade tip to shroud gaps
- With Length or Point to Line for small features when unable to get closer
- With Area Depth Profile when measuring a field of pits on a flat surface
- With Depth Profile when you cannot fit the cursors fully on a flat reference surface

Effect of a Measurement Plane on other measurement types:

- **Length, Point to Line, Multi-Segment, and Area:** All cursors are projected onto the Measurement Plane, and the result is computed using the projected positions on the plane.
- **Depth:** The first three cursors select individual surface points as with a normal Depth measurement. Only the fourth is projected onto the Measurement Plane.
- **Depth Profile:** The Measurement Plane is used as the reference plane, so the Depth Profile cursors may overlap edges or be in red areas. The result is the height or depth from the Measurement Plane. Use only with flat reference surfaces.
- **Area Depth Profile:** Both reference lines are positioned on the Measurement Plane allowing them to pass through red areas or surface pits without affecting the profiles taken between the reference lines. The result is the height or depth from the Measurement Plane. Use only with flat reference surfaces.
- Only one Measurement Plane can be used on an image.
- If a Measurement Plane is present, all other measurements use it regardless of the order in which they were placed.

Measurement Plane EVA Warnings



When using a Measurement Plane with Point to Line, Area, or Depth to measure near an edge, the viewing perspective can affect accuracy, especially if the edge has a significant radius. To help the user maximize accuracy, the system displays an Edge View Angle (EVA) value next to the MTD and an Edge View Angle Line (EVA Line) in the point cloud views. The ideal EVA of 0° occurs when the EVA Line is perpendicular to the Measurement Plane. Measurement error generally increases as the EVA increases when measuring near a rounded edge. If the EVA exceeds an upper limit (25° for Point to Line, 35° for Area and Depth) with cursors placed near an edge, the system displays a warning message, flashes an orange outline around the MTD and EVA, and shows the EVA Line in orange. To reduce the EVA, inspect the Full Image point cloud, in which the four dotted 3D Perspective Lines show the corners of the field of view, and visualize how the relative positions of the tip and the object must be adjusted to make the EVA Line more perpendicular to the Measurement Plane, shown as a solid blue rectangle. Capture a new image with the adjusted positions, and repeat the measurement.

Some points regarding the Edge View Angle (EVA):

- It is the angle between the Measurement Plane and an Edge View Plane determined using two 3D coordinates on the edge and the origin of the field of view where the four dotted 3D Perspective lines in the Full Image point cloud converge. To help visualize this concept, open the front cover of a hardcover book and hold the edge of the cover up close to your eye. The cover represents the Edge View Plane, the first page represents the Measurement Plane, the joint between them represents the edge of the surface, and the angle between them represents the EVA.
- Moving cursors along a straight edge has little impact on the EVA because the Edge View Plane does not change.
- The EVA depends on the position of the edge in the image. The top left image shows a poor EVA when measuring near the left side of the image with a perpendicular view at the center. The right image shows a much better perspective at the part edge, which is reflected in the low EVA.
- Rotating a side-view tip in a fixed position (e.g., borescope port) has little impact on the EVA. Movement of the viewed object or translation of the tip is generally needed.
- As shown in the lower left image, achieving a low EVA does not require a perpendicular view of the part. In the book analogy, you can tilt and move the book while maintaining a 90° angle between the cover and the first page.
- If the edge along which the measurement is performed has a small edge radius relative to the measured dimension, accurate results can be achieved even with an EVA warning present when the edge is coming toward the probe tip. Avoid measuring with high EVA values on edges going away from the tip.
- See the “Measurement Plane Guide Lines” section for measuring on rounded edges with high EVA values.



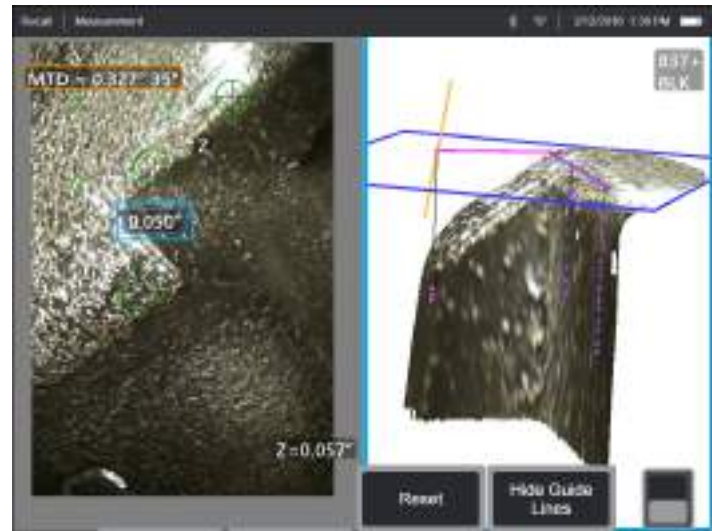
Measurement Plane Guide Lines



Guide Lines are shown in the point cloud views when using a Measurement Plane with Length, Point to Line, Multi Segment, or Area. They are shown as black lines that are perpendicular to the Measurement Plane and extend from the cursor locations on the Measurement Plane to surface points straight above or below the cursor locations. Spheres are shown where Guide Lines intersect the surface.

Example Applications:

- Edge damage on rounded turbine blade or vane edges
- Turbine vane platform to shroud gaps
- Edge radius estimates
- Gap width
- Any in-plane dimensions between points not on the same plane



Best Practices to Improve Measurement Accuracy:

- Adjust the cursor positions in the 2D image until the Guide Lines and surface spheres appear on the surface in the desired locations.
- Use when measuring on rounded edges and an in-plane measurement like that obtained using an optical comparator is desired. The conventional Point to Line measurement of a rounded leading edge indication in the lower left image is on a diagonal and therefore gives a larger result than would be obtained using an optical comparator. The same indication is measured in the top left image using a Measurement Plane with Guide Lines to remove the angle.
- Cannot be reliably used if the EVA is more than about 10° and the rounded edge is away from the probe tip.
- Cannot be used when the 3D data does not extend all the way to the edge of the surface.
- Should be used to guide cursor positioning on rounded edges oriented toward the probe tip, especially when the EVA exceeds about 15°. The rounded edge is off the measurement plane, so unless the EVA is low, the cursors cannot be placed properly using only the 2D image. This is especially true with higher EVA values that generate warnings as shown in the above two images.



Conventional Measurement on a Diagonal

Measurement Plane Examples

Turbine blade missing corner dimensions:

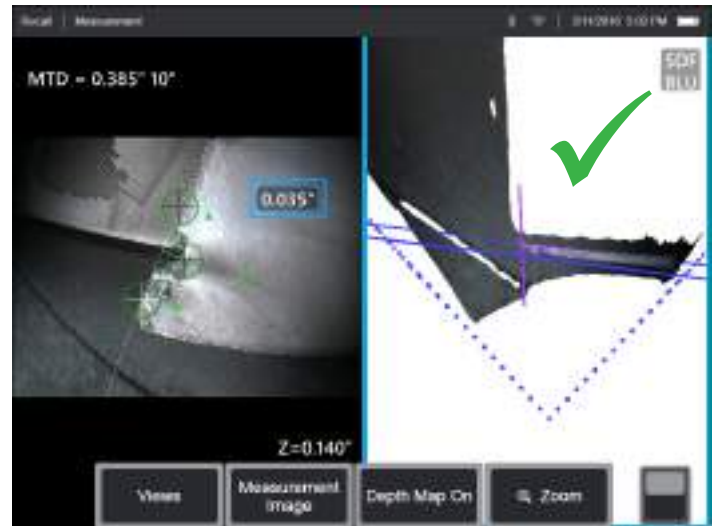
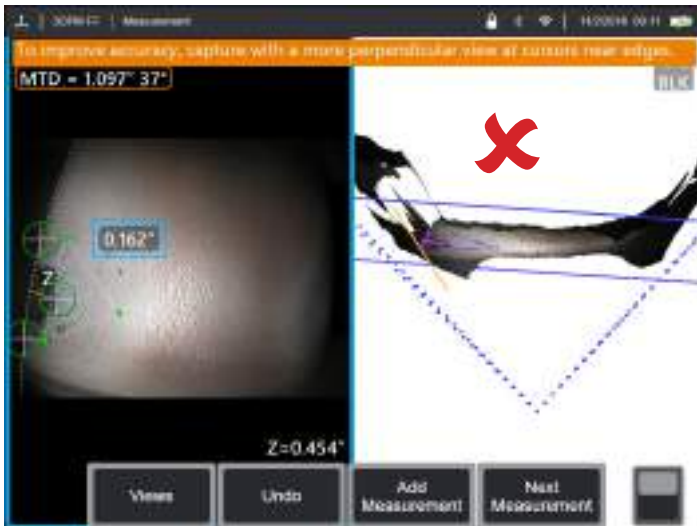
- Use a Measurement Plane with Area.
- Position the probe tip according to recommendations in the Measurement Plane EVA Warnings section.
- Place the Measurement Plane on the face of the blade near the missing corner.
- Place an Area measurement with one cursor on each remaining corner, one cursor out in space where the corner used to be, and as many as are needed to follow the broken edge.
- After pressing “Done”, adjust the cursors so that the extended lines line up with the blade edges near the missing corner region.
- The missing area, missing edge dimensions, and the corner angle are all provided eliminating the need for additional measurements.



Turbine blade edge indication:

- Use a Measurement Plane with Point to Line when 3D data along the blade edge is missing or noisy.
- Position the probe tip according to the recommendations in the Measurement Plane EVA Warnings section.
- Place the Measurement Plane on the face of the blade near the indication.

- Add a Point to Line measurement with the first two cursors placed on the edge of the blade and the third at the inner edge of the indication.
- The Edge View Angle (EVA) is displayed next to the MTD. The lower the EVA, the better the accuracy, especially when measuring on a rounded leading edge. When making a critical call, try to achieve an EVA of less than 15°.



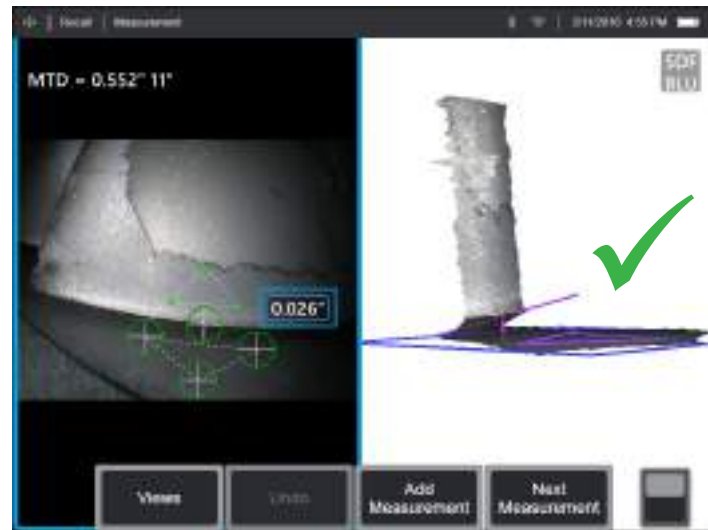
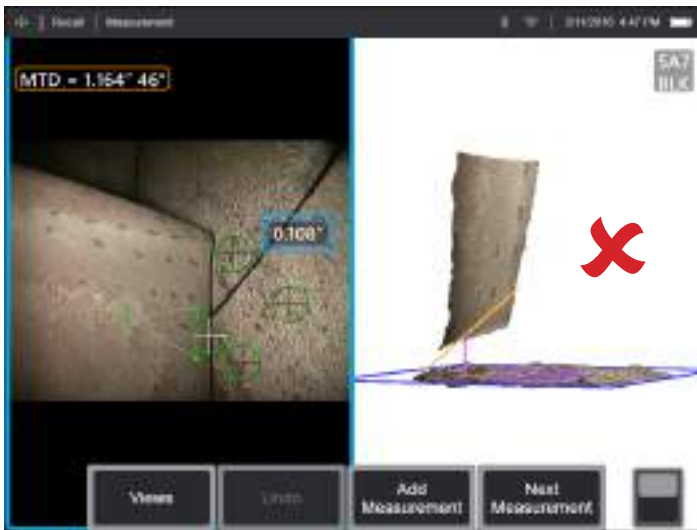
Measurement Plane Examples

Turbine blade tip to shroud clearance:

- Use a Measurement Plane with Depth when 3D data at the edge of the blade is missing, noisy, or drawn down and back toward the shroud as shown in the lower right image.
- Position the probe tip low to the shroud so that you can see back under the blade. The left image below is captured from too far above the shroud as indicated by the 46° EVA.
- Place the Measurement Plane on the face of the blade near the desired measurement point. Too much spacing between the cursors near the blade edge can increase error due to blade

curvature.

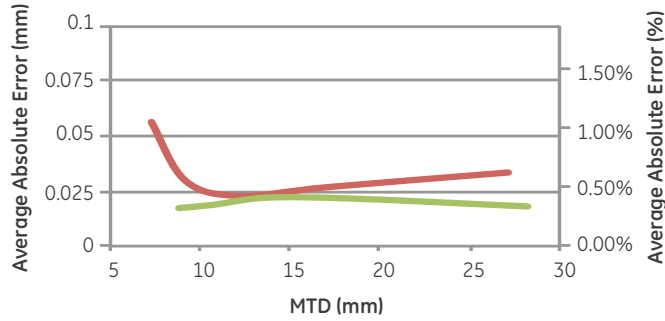
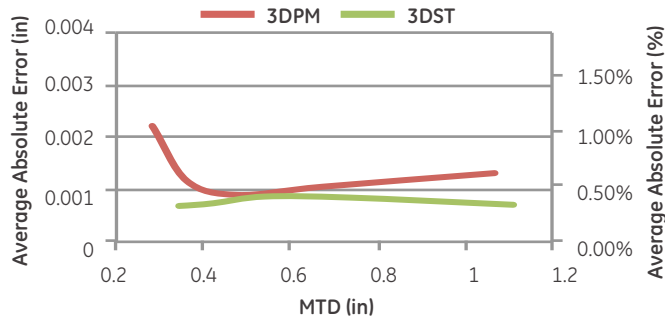
- Place the first three Depth cursors on the shroud.
- Position the fourth Depth cursor at the edge of the blade in the 2D image. This cursor is projected onto the Measurement Plane, so it may appear slightly off the edge in the point cloud due to missing or noisy 3D data at the edge.



MEASUREMENT ACCURACY DATA

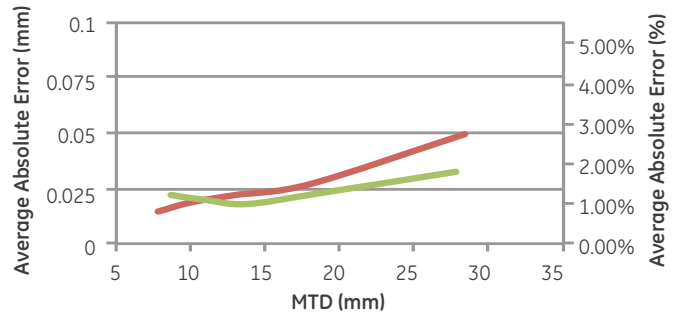
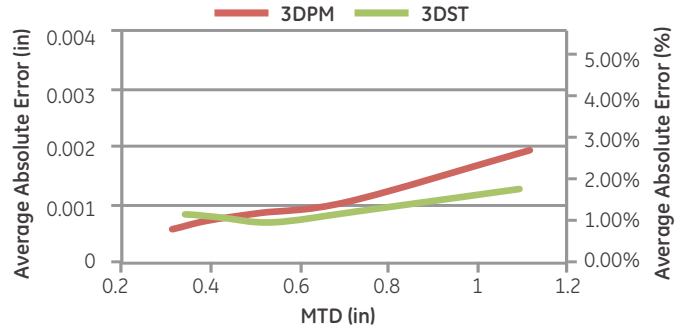
The measurement accuracy curves on pages 18-19 were created from trained third party test results using 6.1 mm diameter 3DPM and 3D Stereo (3DST) on a Mentor Visual IQ under controlled conditions with a matte finish test block. They should be interpreted as system capability under ideal conditions. Actual results vary with application, surface conditions, equipment condition, and user expertise.

Length Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.21" (5.33 mm) Long Feature



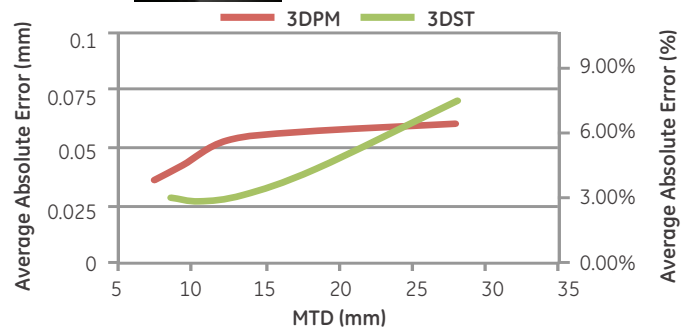
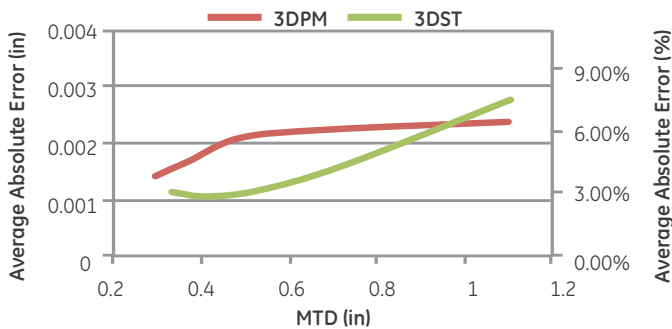
Accuracy curve for length measurement of a crack.

Pt-Line Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.071" (1.803 mm) Edge Ding Feature



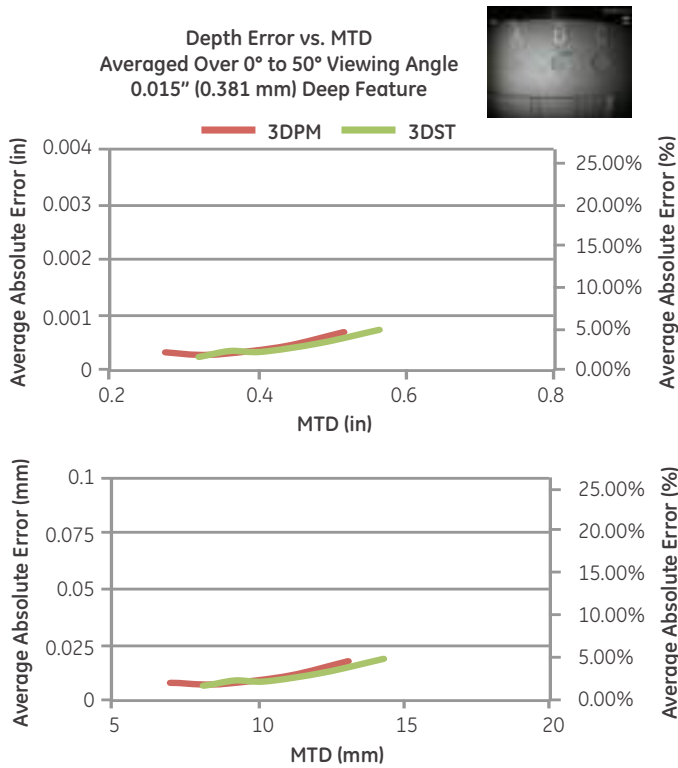
Accuracy curve for point to line measurement of an edge ding.

Pt-Line Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.037" (0.94 mm) Missing Corner Feature

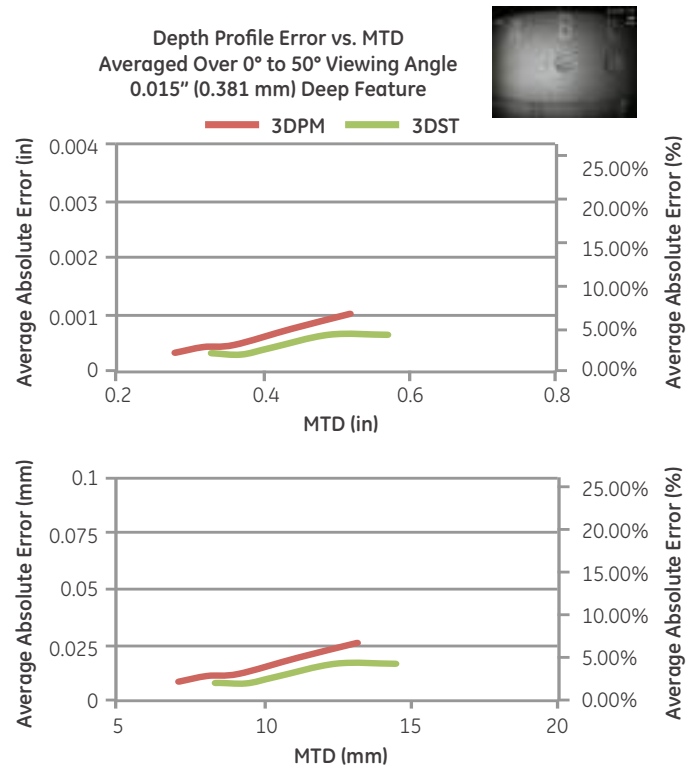


Accuracy curve for point to line measurement of a missing corner.

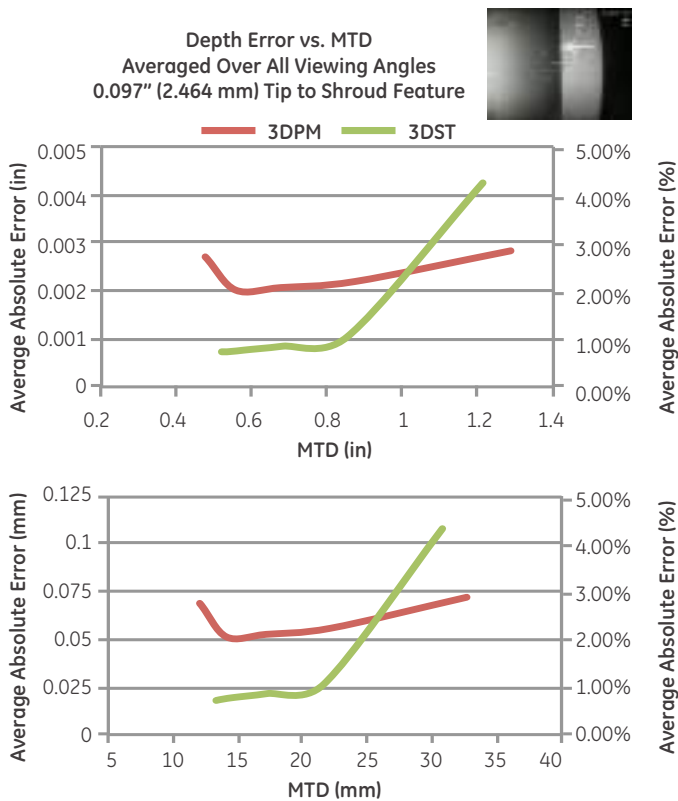
Note: Measurement Planes were not used in this testing but would likely improve the results on some features.



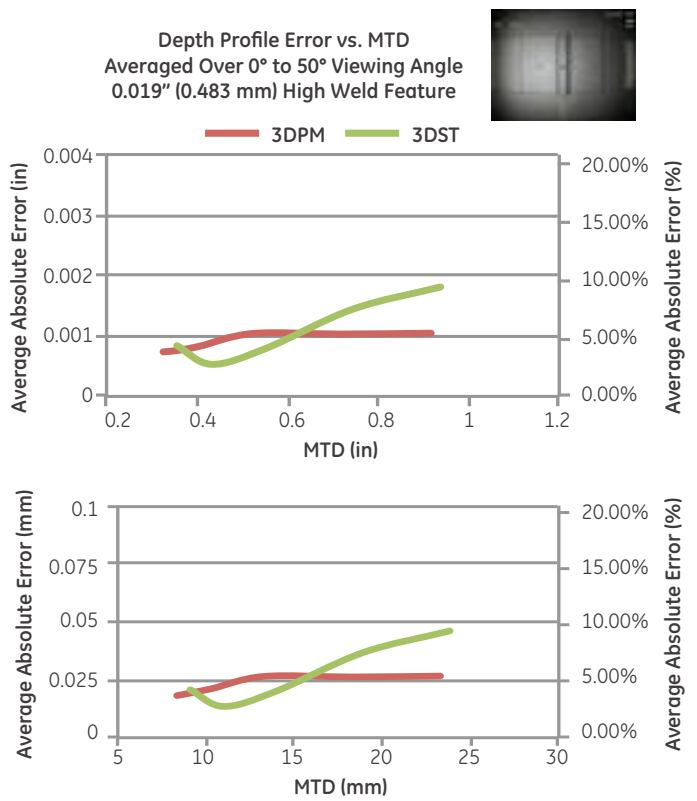
Accuracy curve for depth measurement of a pit or dent.



Accuracy curve for depth profile measurement of a pit or dent.



Accuracy curve for depth measurement of a tip to shroud distance.



Accuracy curve for depth profile measurement of weld height.

SPECIFICATIONS

Measurement Tip Optic Specs and Part Numbers for Mentor Visual IQ

Mentor Visual IQ 4.0 mm Tips

3D Stereo Measurement and Stereo Measurement Tips

Part No.	Color	FOV (deg)	DOF mm	(in)
TM405555FG	Black	55/55-FWD	5-inf	(.20-inf)
TM405555SG	Blue	55/55-SIDE	4-inf	(.16-inf)

Mentor Visual IQ 6.1mm Tips

3D Phase Measurement Tips

XL4TM61105FG (forward version)	Black	105	8-250	(.31-9.84)
XL4TM61105SG (side version)	Blue	105	7-250	(.27-9.84)
XL4TM61105FN-8651	Orange	105	3-120	(.12-4.72)

3D Stereo Measurement and Stereo Measurement Tips

XLG3TM616060FG	Black	60/60-FWD	4-80	(.16-3.15)
XLG3TM615050SG	Blue	50/50-SIDE	2-50	(0.8-1.97)

Mentor Visual IQ 8.4mm tips

3D Stereo Measurement and Stereo Measurement Tips

XLG3TM846060FG	Black	60/60-FWD	4-50	(.16-1.97)
XLG3TM846060SG	Blue	60/60-SIDE	4-50	(.16-1.97)

Measurement Software Part Numbers

3D Stereo Measurement	MVIQ-3DPM
3D Phase Measurement	MVIQ-3DST
Stereo Measurement	MVIQ-ST
Projected Plane Measurement	MVIQ-PPM
Area Depth Profile	MVIQ-ADP

Glossary

3D Data Mask – Shows red and yellow pixel masks. See "Red Mask on Image" and "Yellow Mask on Image" for details.

3D Perspective Lines – Dotted blue lines showing the four corners of the tip field of view in the full image point cloud to help the user understand and improve tip orientation relative to a surface. May be shown or hidden via the settings menu.

3D Phase Measurement – A measurement technology that projects line patterns on an object via a series of LEDs. Measurements are calculated using the concept of phase shift analysis combined with proprietary processing technology.

3D Point Cloud – A 3D graphical representation of the surface being inspected with lines and spheres added to show measurements made on that surface. The 3D point cloud can be rotated and viewed from multiple angles and perspectives. It allows an inspector to check the setup of their measurement and cursor placement points.

3DPM Range Guide – Visual aid displayed when viewing live video with a 3DPM tip attached to indicate the system's ability to achieve sufficient brightness with the tip LEDs for a high-quality scan. Increasing the number of bars by moving closer to the target will increase 3D data quality and measurement accuracy.

3D Stereo Measurement – Uses the same optical principles as Stereo Measurement and combines these with the ability to create, manipulate and analyze a 3D Point Cloud representation of measurement data.

3D Surface Mask – Colored semi-transparent masking of surface points in the 2D image and point cloud views during 3DPM or 3D Stereo measurement that helps guide proper cursor placement.

Active Cursor – The cursor currently being manipulated, indicated by a blue circle.

Advisory Message – "For best results the reference cursors should be on the same plane" – In depth profile measurement, indicates the reference cursors are not on the same plane.

Advisory Message – "Move closer to target or move cursors for better results" – Indicates that the measurement is too small to be reliable at the current tip to target distance. Can be remedied by moving tip closer to the indication or selecting larger measurement area.

CSV – Comma separated value, used for point cloud file data export. Can be opened in a CAD package.

Depth Assist – Feature wherein the the system searches the surface data in the vicinity of the first three cursors of a Depth measurement and automatically places the fourth cursor at the deepest point, highest point, or a point on a blade tip saving the user the time of locating those points manually.

Depth Map – 3D point cloud viewing mode in which either the tip to target distance (full image) or the perpendicular distance from the measurement reference plane (measurement image) is color coded to provide better understanding of 3D data noise levels and surface contours.

Depth Profile View – Alternative 2D view of depth profile along a selected depth profile line.

Edge View Angle (EVA) – Displayed next to the MTD to help the user gauge the suitability of the viewing perspective when making a Point to Line, Depth, or Area measurement near the edge of a surface using a Measurement Plane.

Edge View Angle Line (EVA Line) – Line shown in the point cloud indicating where the EVA is determined. The EVA is 0° when the EVA Line is perpendicular to the measurement plane.

FOD – Foreign Object Damage.

Full Image Point Cloud – Shows all measurements and surface data. The depth map indicates the distance from the measurement tip to the surface.

Guide Lines – Lines shown in the point cloud views when using a Measurement Plane with Length, Point to Line, Multi Segment, or Area to help the user position cursors to align with out-of-plane surface points.

InspectionWorks Connect – Remote collaboration tool allowing live remote viewing of inspection video, two-way chat and annotation. Can be activated directly on the Mentor iQ handset.

Inactive Cursor – Cursors not currently selected, indicated by a green circle.

Inspection Manager – PC-based re-measurement tool for visual inspection images.

Measurement Image Point Cloud – Shows only the active measurement and surface data in its vicinity. The depth map indicates the perpendicular distance of the surface points from the measurement's reference plane.

Missing Corner – The corner of a turbine blade that has been broken off usually by a foreign object passing through the turbine.

MTD – Maximum target distance. Identifies the distance of the furthest cursor point in a given measurement from the tip of the probe.

Noise in the Point Cloud – Artifacts in the 3D data not representative of true surface geometry. Noise is generally reduced by moving the tip closer to the target surface or changing angle of approach to reduce reflections.

Orange Outline Around Measurement Results and MTD Value – Indicates that the measurement is too small to be reliable for the current tip to target distance. Can be remedied by moving tip closer to measurement or selecting larger measurement area.

Profile Slices – Paths along the surface between the reference profile lines in an Area Depth Profile Measurement that map the perpendicular distance between the surface points and the reference surface.

Projected Plane Measurement – The use of a Measurement Plane in combination with another measurement type to mathematically project the plane of a surface over the entire image and measure on that plane.

Red Filled Cursors on Depth Profile – Indicates cursor is not on a flat surface or not on the same plane. Cursor must be repositioned for accurate measurement.

Red Mask on Image – Indicates surface data in this area is not available for measurement. Moving closer or adjusting viewing orientation may reduce red mask area.

Reference Line – In a point to line measurement, the first two cursors, placed on unaltered surface points, define a straight reference line in 3D space from which the distance to the third cursor point is measured.

Reference Plane – The plane, defined by three or more points on a reference surface, from which the perpendicular distance to other surface points is computed. A blue square indicates the reference plane position in the measurement image 3D point cloud view.

Note: A reference plane is calculated as flat, even if the surface the plane rests on is not flat. This is a potential source of error.

Reference Profile Line – Area Depth Profile lines set by the measurement cursors that follow the surface contours and are used to determine the area and reference planes for the profile slices.

Reference Surface – Unaltered part surface to be used as a reference for various measurements.

Result Slice – The Area Depth Profile profile slice that includes the highest or lowest point and is shown on the image and in the point cloud.

Yellow Mask on Image – With 3D Phase Measurement, indicates surface data may be of low quality for measurement. The potential for reduced accuracy may exist, especially for depth or small measurements. Yellow mask areas are often caused by surface to surface reflections. Changing the probe orientation to make such reflections bounce away from the probe tip may improve data quality and reduce or eliminate yellow mask areas.



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