

Real3D™ 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*.

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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, you could identify indications and capture images; today's advanced video borescopes allow you to map, measure, and analyze indications in 3D and, with InspectionWorks, to share live inspections, images and data wirelessly to a phone or tablet locally or to 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. [Advanced training is available through the Waygate Inspection Academy.](#)

The Importance of Measurement Precision & Accuracy

Remote Visual Inspection (RVI) 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 you 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, you have 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 and inconsistent measurements and potentially costly incorrect decisions.

The latest Real3D™ Measurement technologies allow the real-time use of a 3D XYZ fully surfaced point cloud to check data quality and assist the inspector in placing cursors from multiple angles and perspectives.

Accurate VideoProbe™ measurement requires:

It is recommended that 0.125mm (0.005") be considered the minimum feature size for measurement. Under ideal conditions, a general guideline to consider when measuring these smaller features is that Real3D Phase and Real3D Stereo measurement usually can achieve errors in the +/- 0.05mm (+/- 0.002") range or better on both length and depth type measurements.

Caution: *This does not express or imply that you will be able to achieve these results for all measurements attempted. A Gage R&R study will determine expected results for any given measurement requirements using a VideoProbe.*

Ideal conditions vary by measurement technology as described below.

Real3D Phase Measurement ideal conditions

- Measurements by a trained, qualified RVI technician
- Clean and calibrated optical tip adapters (OTAs) and camera lens
- Camera positioned very close to the indication, even if slightly out of focus
- Camera positioned in a non-perpendicular incident angle to the surface
- Measurement upon a matte, non-reflective surface finish
- Minimal or eliminated reflections and shadows of structured light
- Absence of ambient light
- Systems may be unable to both view and illuminate the bottom of narrow, deep features with either structured light patterns or normal illumination, making them unable to determine accurate 3D data at the bottom of such features.

Real3D Stereo and Stereo Measurement ideal conditions

- Measurements by a trained, qualified RVI technician
- Clean and calibrated OTAs and camera lens
- Camera positioned very close to the indication, and in sharp focus
- Measurement on surfaces that are feature-rich and not bland
- No glare on the indication
- Pixel pattern differentiation around the indication

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 Global 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 Global is available as an option on all models of Mentor Visual IQ.

Additionally InspectionWorks Local + Control (available on iPhone or iPad devices) provides point to point streaming, remote control and file transfer in both wired and wireless configurations.

Measurement Technologies

(See Mentor Visual iQ VideoProbe™ Operating 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
- Green side view tip provides ability to measure larger areas

3D Stereo Measurement

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 or view the 3D surface topology of the inspection target area.

Benefits:

- More accurate, precise measurement compared to traditional or manually matched stereo 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, especially when using Image Brightness and Dark Boost
- 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.

Inspection Manager

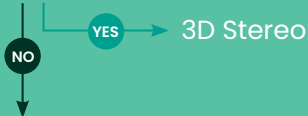
Inspection Manager is a Windows PC-based software tool which allows the re-measurement and analysis of any measurement image captured by a Waygate Technologies VideoProbe. The tool allows you to move measurement cursors, add measurements, or completely clear out previous measurements and begin a new measurement process. If the measurement image was captured with a 3D-Stereo or 3D-Phase process, this tool also allows full point cloud viewing and manipulation.

3D Measurement Best Practices: Techniques and Tips

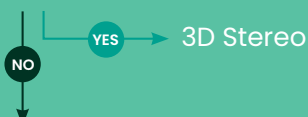
These best practices apply to both 3D Phase Measurement and 3D Stereo Measurement. Use this best practice guide to provide the best results when setting up measurement with your VideoProbe. Additional guidelines for specific measurement types are listed in each measurement type section.

Choose the Right Real 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?



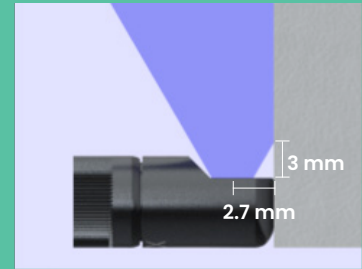
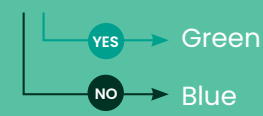
Is a forward-view tip required?



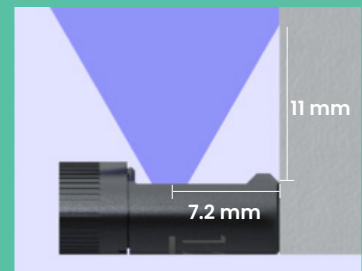
Do the viewing optics need to be very close to the end of the side-view tip to see into the inspection area due to mechanical obstructions?



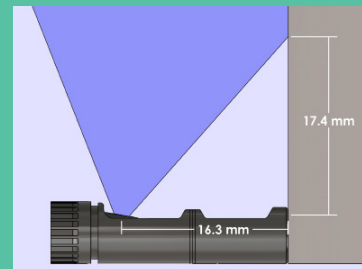
Is the tip-to-target distance greater than 25mm?



3D Stereo Side View



3D Phase Blue Side View



3D Phase Green Side View

- Use 3X patented Zoom window for more precise cursor placement; this is most helpful on length and point measurements, especially important for small indicators.
- Utilize 3D surface mask to optimize cursor placement
- New Inverse+, HDR Variable and Dark Boost image transforms to aid in indication analysis
- Review and reposition cursors in the white light or point cloud for best precision and accuracy

General Guidelines

- Ensure the inspector is trained and qualified to perform measurement.
- Use in-house procedures and 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.
- Be mindful to maximize the fringe patterns (shadows) on a surface. For Black, Orange and Green Real3D Phase Measurement optical tip adapters' (OTAs), the fringe patterns orientation are horizontally projected. The blue Real3D Phase Measurement fringe patterns orientation are vertically projected.
- Stereo and Real3D Stereo Measurement uses horizontal lines of camera pixels. Surfaces should be vertically orientated in the images, especially if there are repeating patterns in that surface.
- Verify that the system measures accurately with the Waygate Technologies NIST traceable verification block before and after performing measurements. The Orange close focusing forward viewing 3DPM tip can provide clearer images at closer tip-to-target distances.
- Position the tip as close as possible to the measurement area (a high Index or 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 advisory messages displayed by the system during measurement, which may signal improper setup or inappropriate MTD for the measurement performed.
- Check and adjust the measurement setup and cursor placement with 3D point cloud view. Many issues are difficult to recognize using the 2D white light 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, depth profile, or area depth profile measurements. Performing another capture from a different orientation may eliminate the yellow regions.
- When using 3D Phase Measurement, off-perpendicular views yield the best results for depth measurements, especially when measuring objects with shiny surfaces.
- Areas where the system was unable to determine 3D coordinates are highlighted in red. Measurements cannot be taken in these red areas. Measurement data around these unmeasurable areas should be closely evaluated for data validity.
- 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. Measurement data around these unmeasurable areas should be closely evaluated for data validity.
- With 3D Stereo, adjust image brightness, dark boost levels 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



Point to Line

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



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
- Measuring distance to or from a surface's plane



Area Depth Profile

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



Area

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



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 Profile

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



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



Blade Tip Clearance

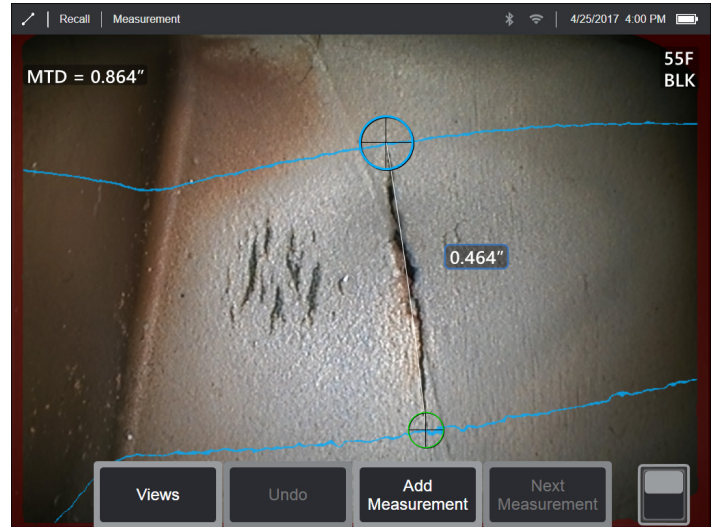
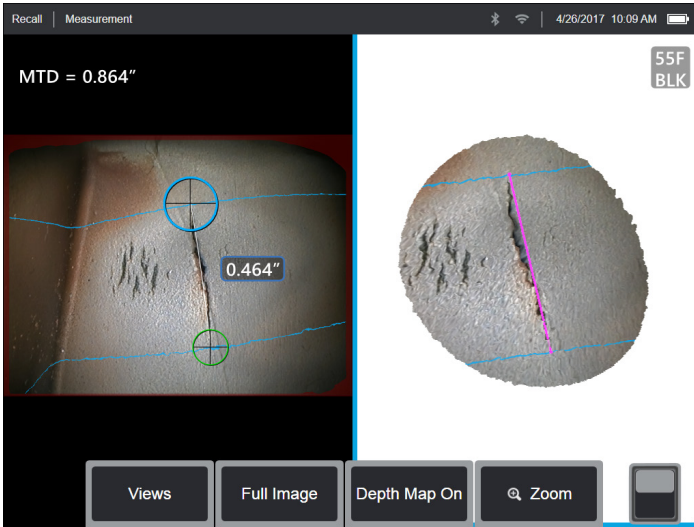
- Turbine production quality assurance
- Compressor and turbine efficiency checks
- Turbine casing ovality assessment

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:

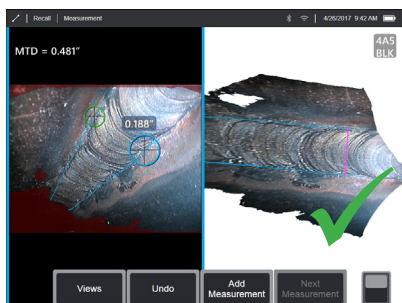
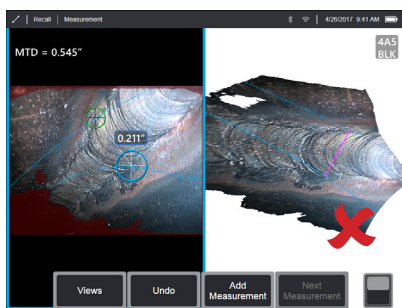
- Simple measurement of features or components
- Indication length measurement (i.e., cracks)
- Measurement of component size migration through expansion or erosion/corrosion/wear
- Determining the remaining size of wear indicators
- Measuring location/zone of indications on a part

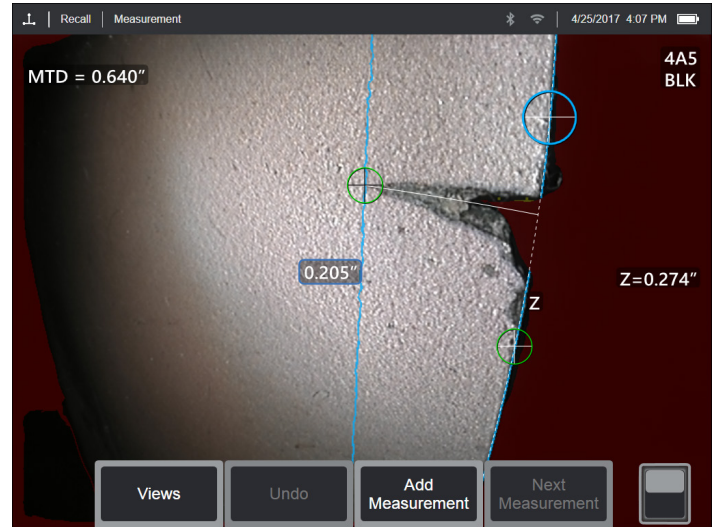
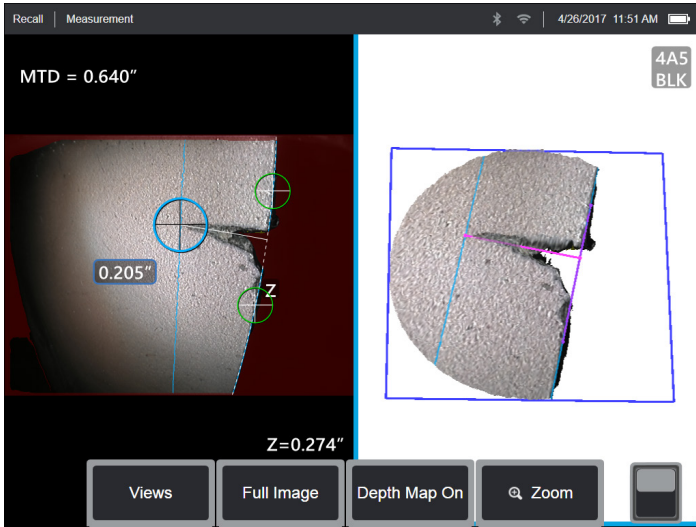
3D Surface Mask:

When enabled in Settings, a blue mask will highlight surface points where planes perpendicular to the straight length 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 in the center of 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.
- The zoom window can be helpful for accurate placement. 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.





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

Example Applications:

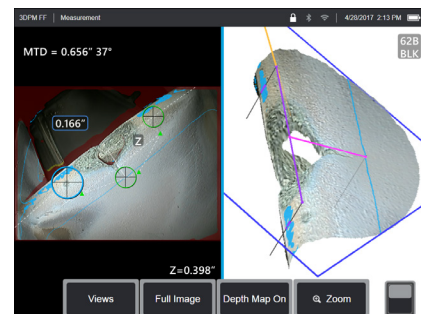
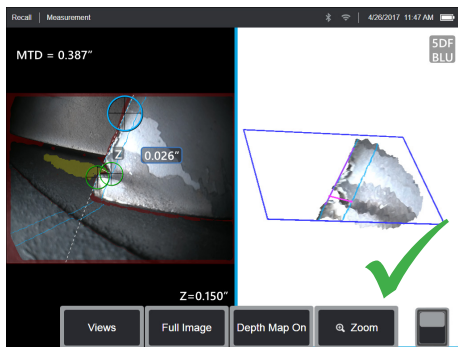
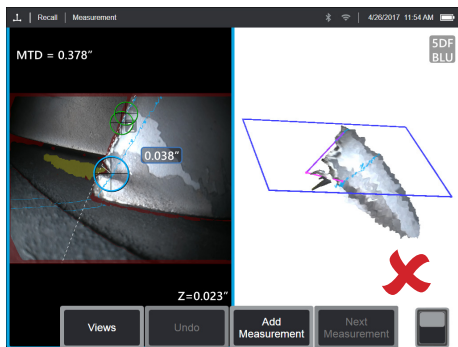
- Turbine blade edge damage
- Estimate missing corner area using multiple point-to-line measurements
- Gap or groove width
- Weld width

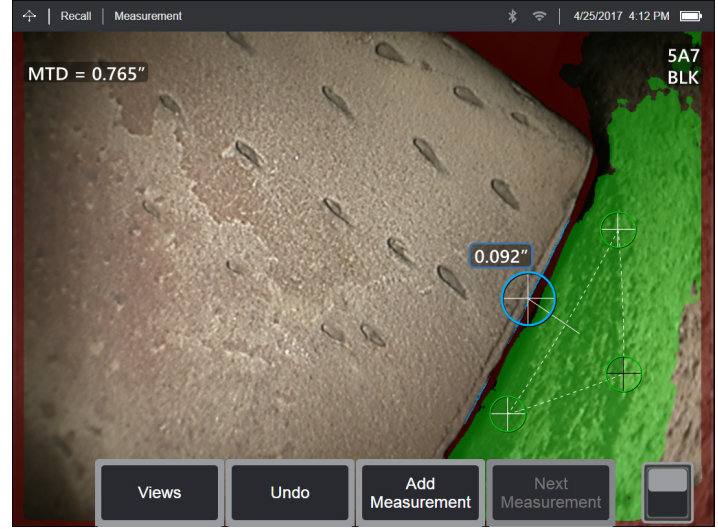
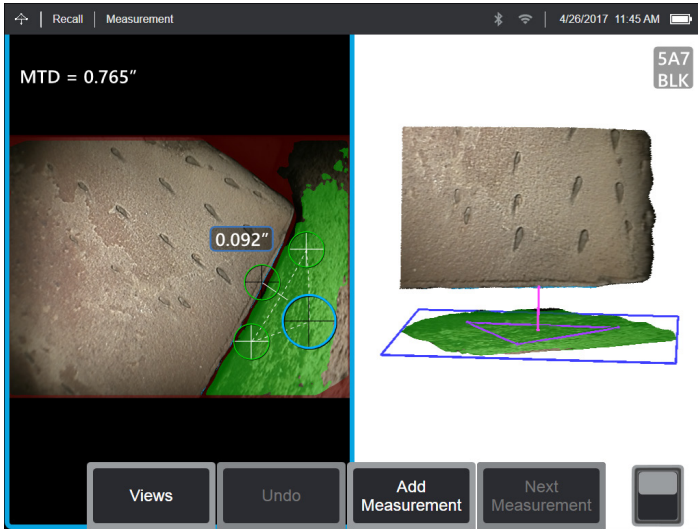
3D Surface Mask:

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.





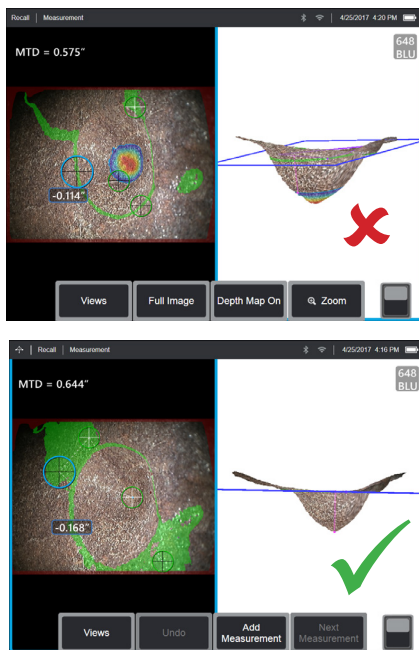
Measures the distance from a reference plane (defined by three selected points) to a fourth selected point above or below the plane.

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:

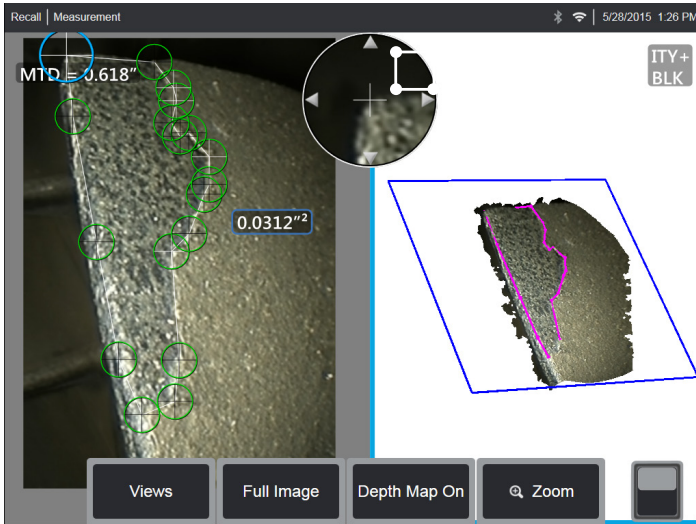
- The measurement tip should be as close as possible to the indication to increase the accuracy of measurement.
- Position the three reference-plane cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface. If measuring a recessed point, use the color gradient to ensure 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.

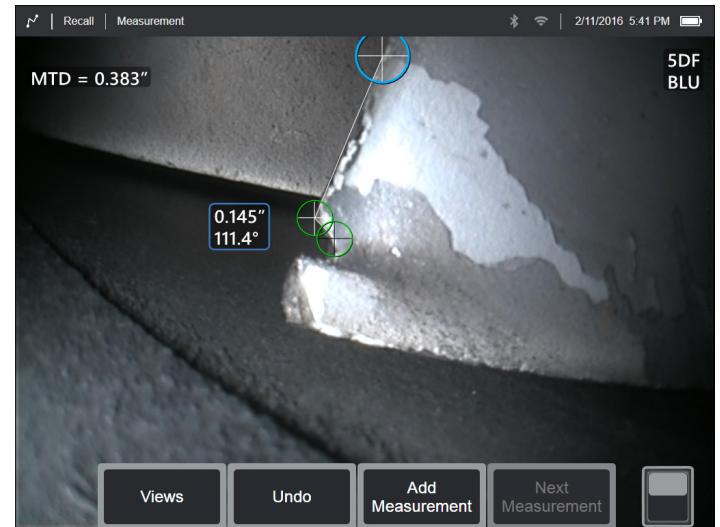
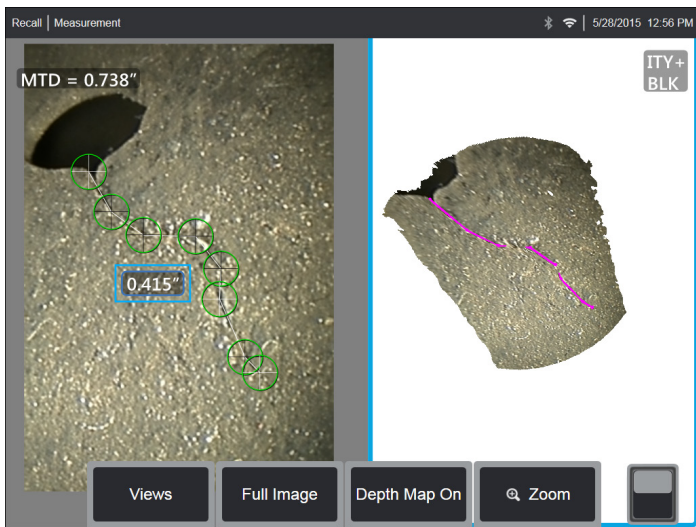
Example Applications:

- 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.

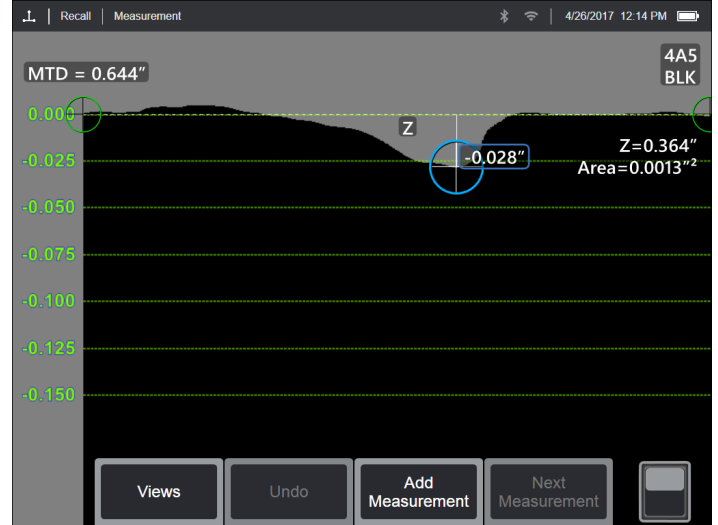
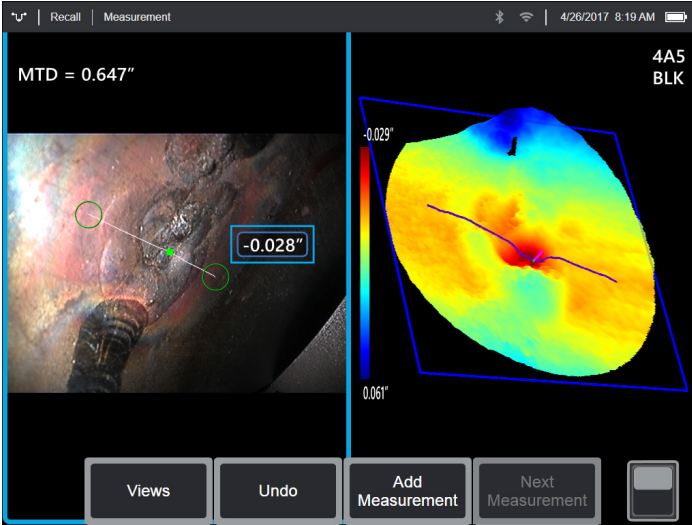
Example Applications:

- 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



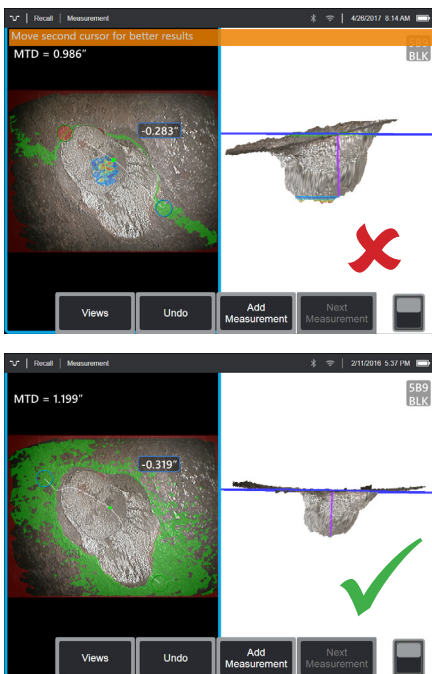
From any viewing angle, maps the perpendicular distance from a reference plane along a line between two selected points and automatically identifies the deepest or highest point.

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

Best Practices to Improve Measurement Accuracy:

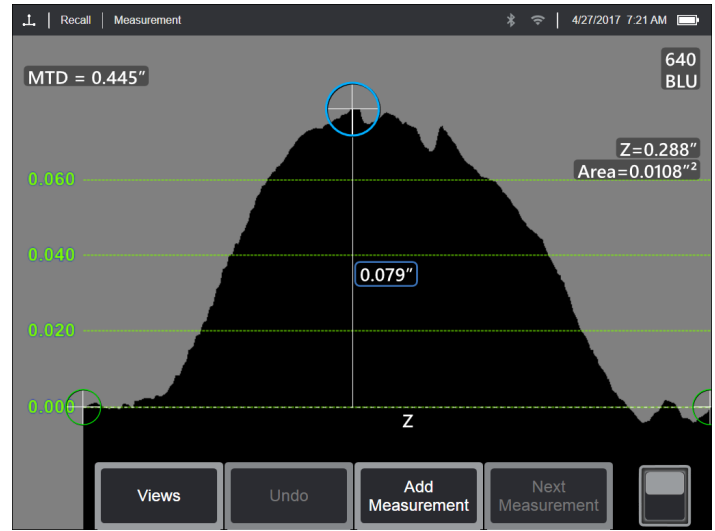
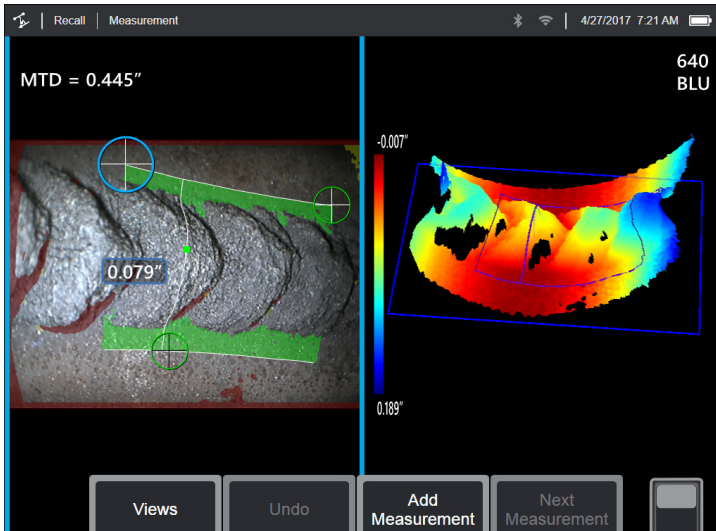
- Position the measurement tip as close as possible to the indication to increase measurement accuracy.
- Position the cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface. If measuring a recessed point, use the color gradient to ensure that the measurement is taken 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.



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 Depth Profile



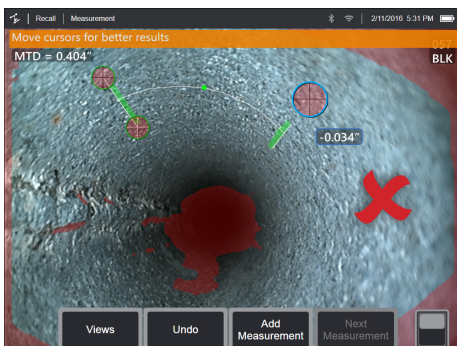
Sweeps a series of depth profile slices over an area defined by three cursors and identifies the profile slice having the highest or lowest point.

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:

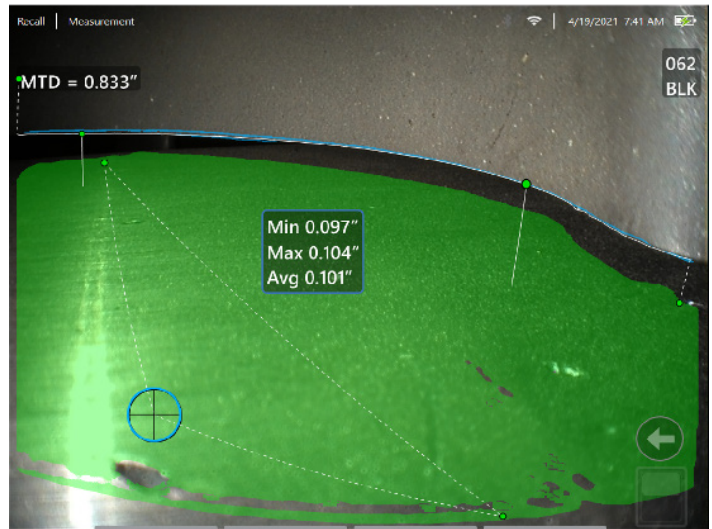
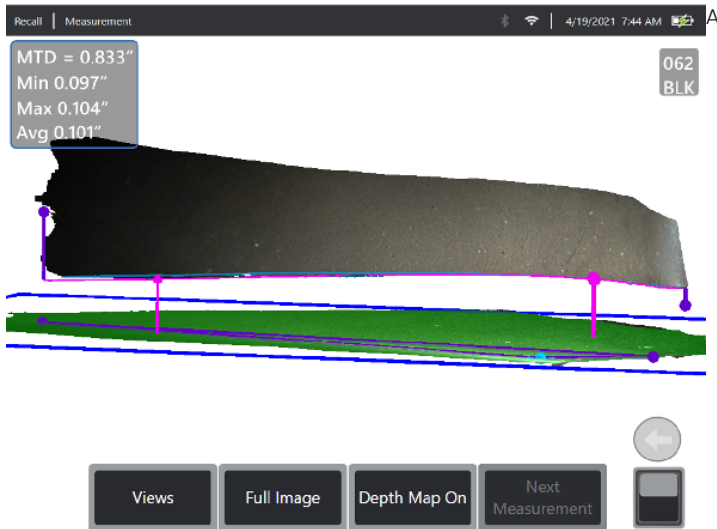
- Position the measurement tip as close as possible to the indication.
- Use with reference surfaces that are flat or have curvature in only one direction, such as a straight section of a pipe. Do not use on surfaces with complex curvatures such as a pipe elbow or turbine blade root at the leading or 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.
- 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.
- 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 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.

Blade Tip Clearance



Automatically identifies the blade and liner, maps the edge of the blade, and determines the minimum, maximum, and average clearance within the mapped blade edge region.

Example Applications:

- TBD

3D Surface Mask:

When enabled in Settings, the 3D Surface Mask shows liner points near the reference plane in green and points offset from the reference plane by either the Min or Max result distance in light blue.

Best Practices to Improve Measurement Accuracy:

Technology Choice

- Both 3DPM and 3D Stereo can be used.
- The 105° FOV of 3DPM tips allows a wider blade tip to be viewed and measured from a given distance than 3D Stereo.
- 3D Stereo may provide better results than 3DPM in compressors having shiny blades and liners.
- With 3DPM, a non-perpendicular view of the blade can improve data quality by directing mirror reflections from the blade and liner away from the camera.
- The 3DPM XL4TM61105SF green tip may be unable to generate 3D data on the liner when inserted

Setup

- Position the probe tip as close as possible to the blade while keeping the blade tip region of interest in the view.
- Position the probe tip with the optics close to the liner to give a clear view of the blade tip and gap.
- Adjust the view to avoid seeing other edges in the image near the blade tip as they may affect the system's ability to accurately map the blade edge.
- If possible, adjust the tip orientation to create a visible dark shadow on the liner side of the blade edge, which helps with blade edge mapping. Rotating the tip such that the viewing

optics are between the illumination exit point and the liner can create this shadowing.

- With shiny compressor blades, use Dark Boost and/or Brightness to optimize visibility of the blade tip with minimal glare near the edge.

Checking the Reference Plane

- The 3D Surface Mask should show green over most of the liner in the vicinity of the blade tip.
- The blue rectangle should line up with the liner in the point cloud view.
- Check the 3D liner data in the point cloud view. If large anomalies are present, adjust the tip position for a view less perpendicular to the blade. Otherwise, manually adjust the 3 liner cursor positions to maximize green mask coverage and improve blue rectangle alignment.

Checking the Blade Edge Mapping

- Verify that the blade edge line closely follows the blade edge in the 2D image.
- Activate the Min and Max cursors and verify in the zoom window that they are accurately positioned on the blade edge.
- Check the point cloud for data quality on the blade near the tip. If significant anomalies exist, adjust the setup and capture a new image.
- Verify that the blade curvature is followed by the blade edge line in the point cloud view.
- Exclude areas near the ends of the mapped edge that are affected by 3D noise, missing corners, etc., from the analysis by moving either bounding cursor away from the edges.
- The algorithm applies fitting and filtering to reduce the impact of small gaps or noise in the blade 3D data. This may result in the blade edge line being slightly offset from the blade edge data in the point cloud view where the gaps or noise exist.



Blade Tip Clearance Advisory Messages

Functionality Notes

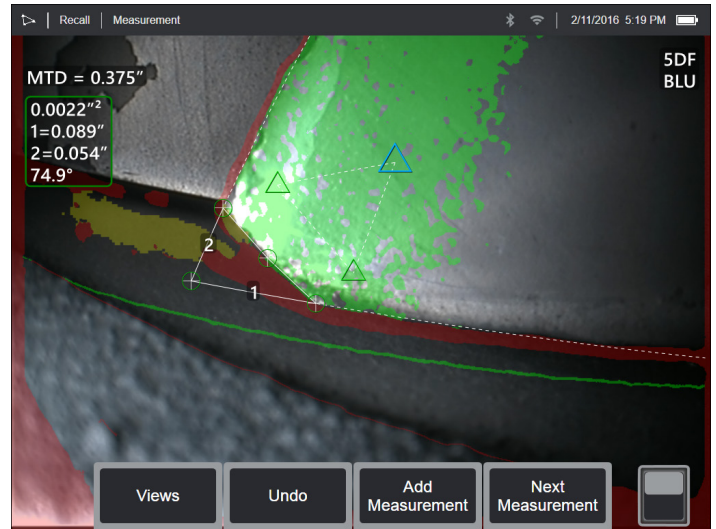
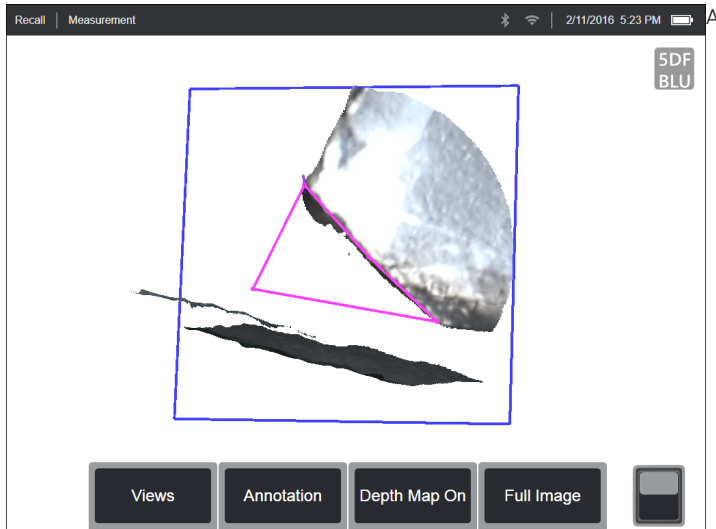
- The blade and shroud can have any orientation in the image.
- Not intended for use with honeycomb liners, turbine blades having outer shrouds, or blades that have irregular tip geometries by design or due to rubs.
- The clearance is measured from a reference plane determined from the 3 reference plane cursor locations. These cursors can be manually re-positioned.
- The algorithm maps the blade edge using the "Normal" 2D image (HDR images are not used). 3DPM pattern images may also be utilized where edge contrast is low in the normal 2D image.
- The pixels near the blade edge must be brighter than those just off the blade edge for successful mapping.
- The Max measurement point is visually differentiated from the Min measurement point by having a larger inactive cursor size.
- The Min and Max cursors cannot be manually re-positioned.
- The two bounding cursors, one at each end of the mapped blade edge, can be moved to exclude end portions from the min/max/average analysis.
- Long touch any shroud cursor to return all 3 shroud cursors to their automatically-chosen positions.
- Long touch either bounding cursor to return it to its automatically-chosen position.
- Use Auto Repeat to improve efficiency when making repetitive Blade Tip Clearance measurements.

Advisory System Checks:

The system looks for several common issues that may degrade accuracy.

- **Shroud 3D data quality may be reducing accuracy:**
The reference plane may not be accurately aligned to the liner in the vicinity of the blade tip due to excessive 3D noise, large gaps in 3D data, or insufficient liner visibility in the view.
- **Blade 3D data quality may be reducing accuracy:**
Excessive 3D noise or large gaps in 3D data exist near the blade edge
- **Move closer to target or move cursors for better results:**
The system may not be capable of accurately measuring a gap of the indicated size from the current tip-to-target distance.
- **To improve accuracy, capture image with tip optics closer to the shroud:**
The viewing perspective may not allow the true blade edge to be accurately mapped and measured.

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. This is accomplished by mathematically extending the measurement plane into 3D space.

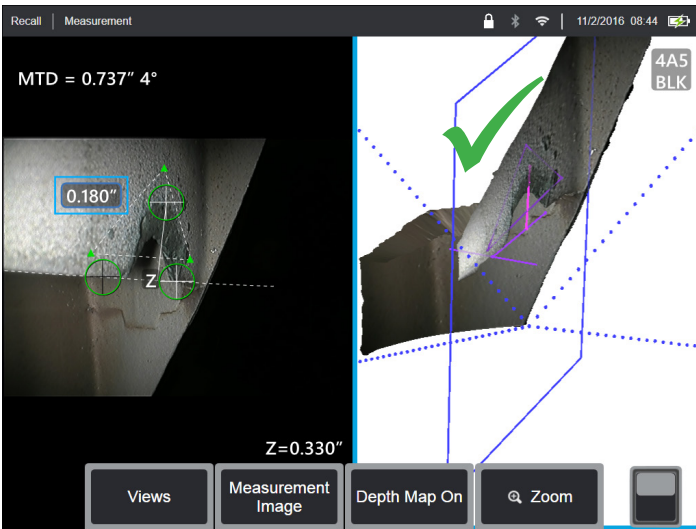
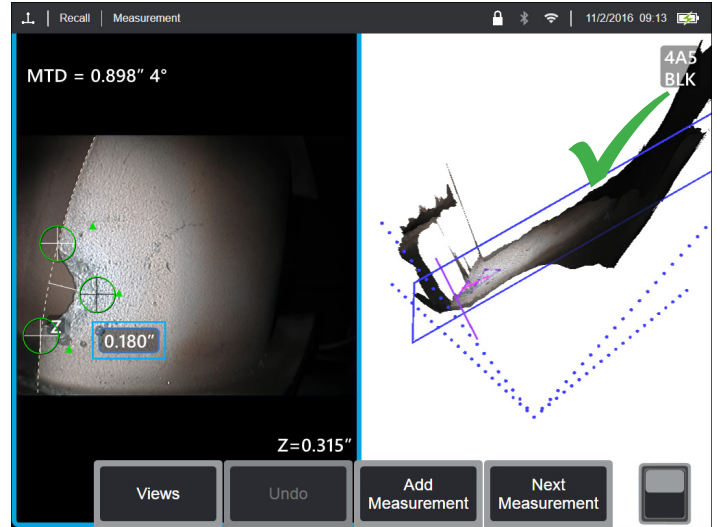
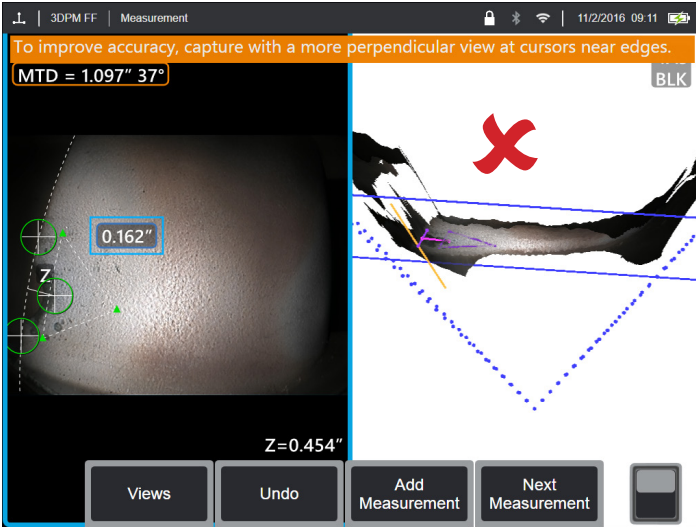
Example Applications:

- 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 Advisory Messages



Some points regarding the Edge View Angle (EVA):

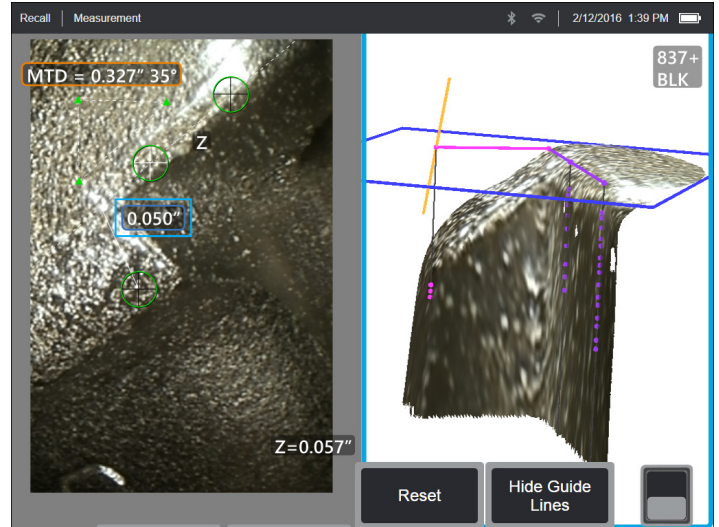
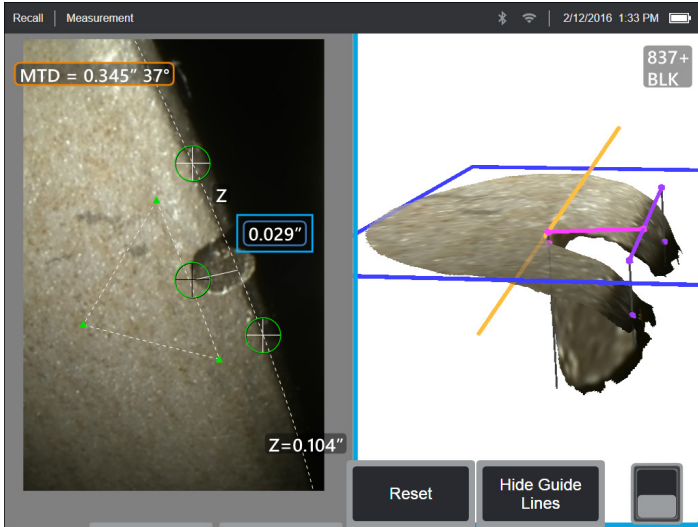
- The angle between the Measurement Plane and an Edge View Plane determined using two 3D coordinates on the edge and the origin of the field of view where the four dotted 3D Perspective lines in the Full Image point cloud converge. To help visualize this concept, open the front cover of a hardcover book 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 top 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 advisory 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.

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 an advisory 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. Find a new image with the adjusted positions, and repeat the measurement.

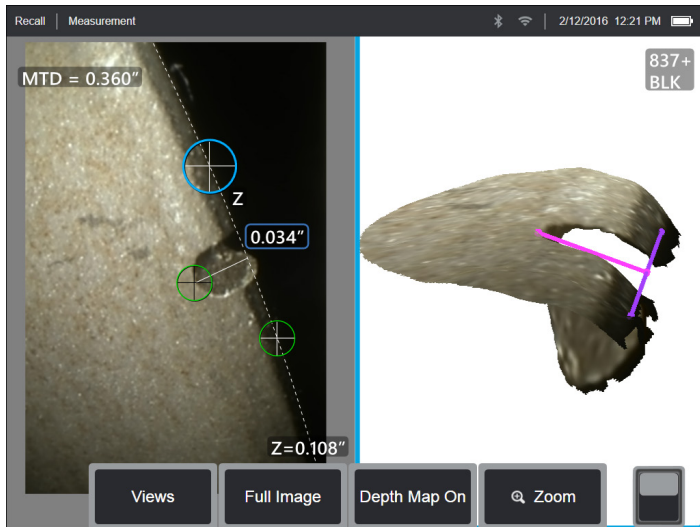
Measurement Plane Guide Lines



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



Conventional Measurement on a Diagonal

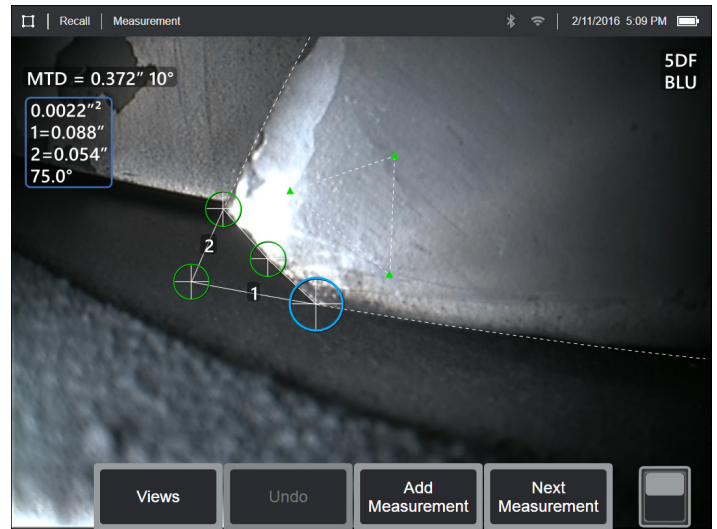
Best Practices to Improve Measurement Accuracy:

- Adjust the cursor positions in the 2D White Light 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 advisory messages as shown in the above images.

Measurement Plane Examples

Turbine blade missing corner dimensions:

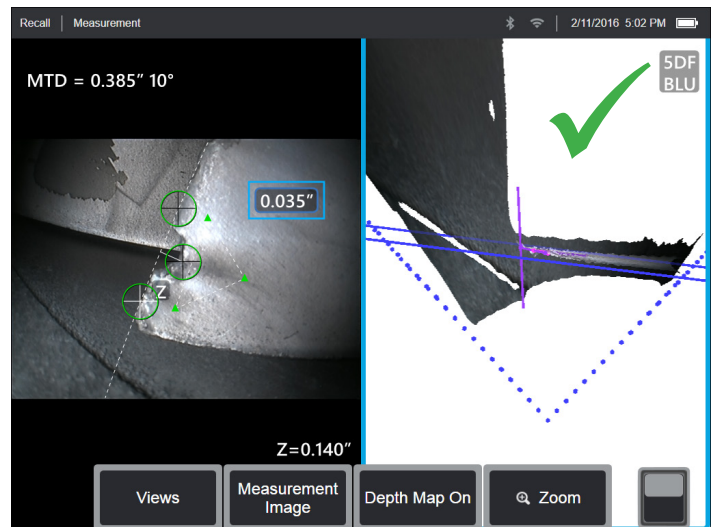
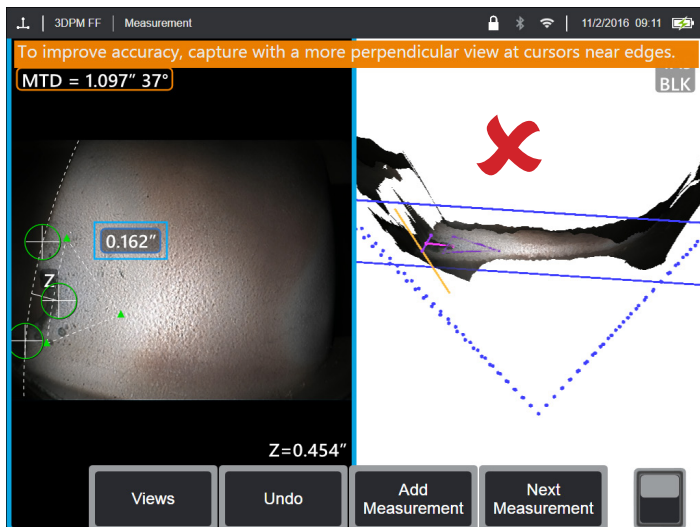
- Use a Measurement Plane with Area.
- Position the probe tip according to recommendations in the Measurement Plane EVA Advisory section.
- Place the Measurement Plane on the face of the blade near the missing corner. Maximize the green surface mask near the area of missing material.
- Place an Area 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. This measurement data field can be moved into position as desired.



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 Advisory section.
- Place the Measurement Plane on the face of the blade near the indication and maximize the green surface mask near the indication and surface edge.

- 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°.

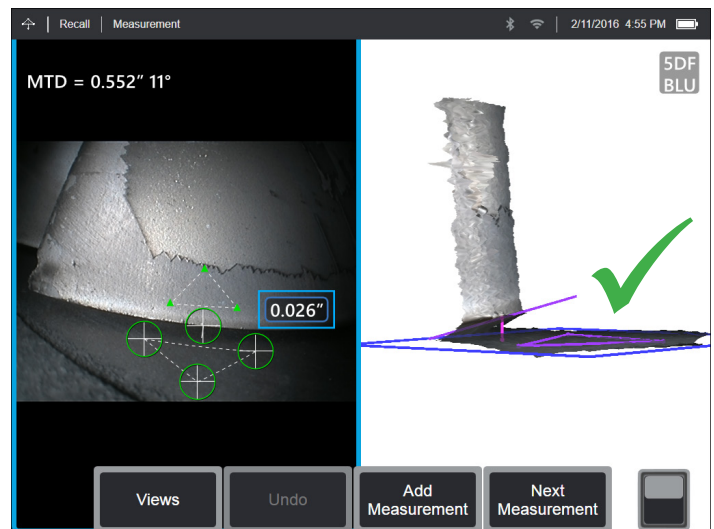
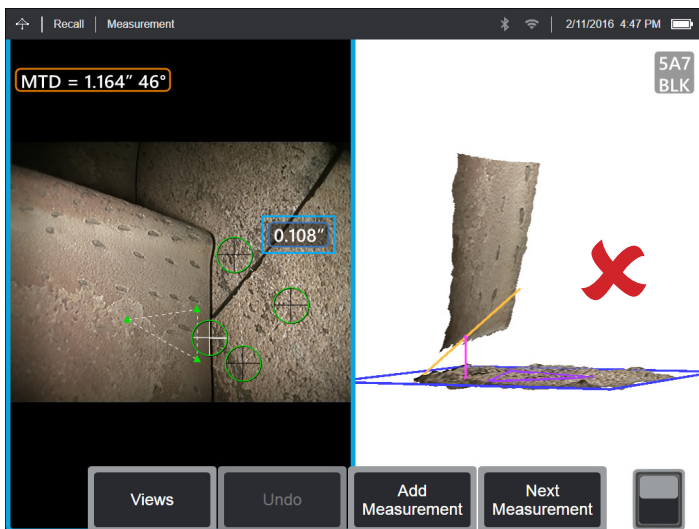


Measurement Plane Examples

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. Look at the green surface mask for cues of this curvature near the area to be measured.

- 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.



It is recommended that 0.125mm (0.005") be considered the minimum feature size for measurement. Under ideal conditions, a general guideline to consider when measuring these smaller features is that Real3D Phase and Real3D Stereo measurement usually can achieve errors in the +/- 0.05mm (+/- 0.002") range or better on both length and depth type measurements.

Caution: This does not express or imply that you will be able to achieve these results for all measurements attempted. A Gage R&R study will determine expected results for any given measurement requirements using a VideoProbe.

Ideal conditions vary by measurement technology as described below.

Real3D Phase Measurement ideal conditions

- Measurements by a trained, qualified RVI technician
- Clean and calibrated optical tip adapters (OTAs) and camera lens
- Camera positioned very close to the indication, even if slightly out of focus
- Camera positioned in a non-perpendicular incident angle to the surface
- Measurement upon a matte, non-reflective surface finish
- Minimal or eliminated reflections and shadows of structured light
- Absence of ambient light
- Systems may be unable to both view and illuminate the bottom of narrow, deep features with either structured light patterns or normal illumination, making them unable to determine accurate 3D data at the bottom of such features.

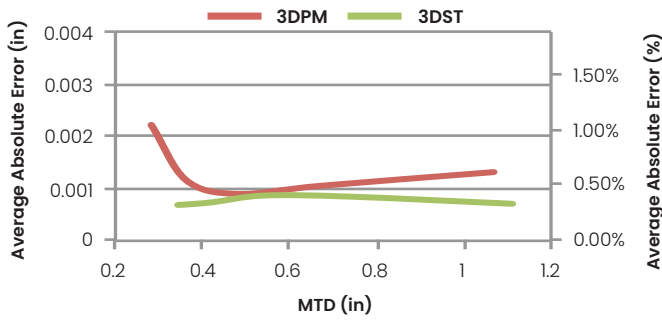
Real3D Stereo and Stereo Measurement ideal conditions

- Measurements by a trained, qualified RVI technician
- Clean and calibrated OTAs and camera lens
- Camera positioned very close to the indication, and in sharp focus
- Measurement on surfaces that are feature-rich and not bland
- No glare on the indication
- Pixel pattern differentiation around the indication

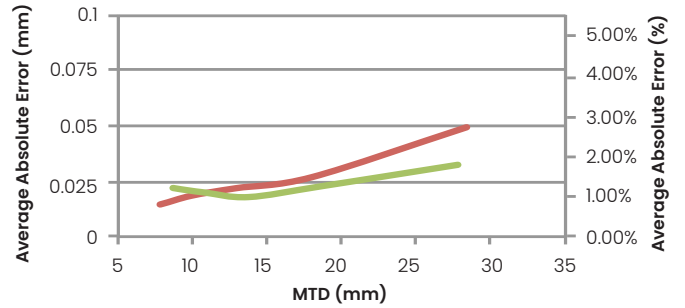
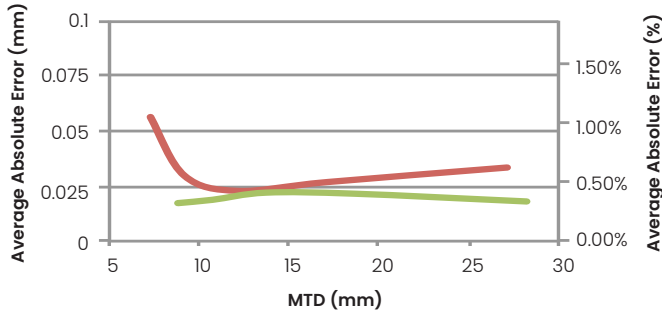
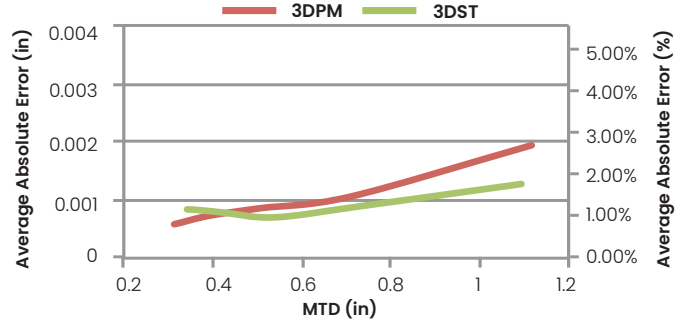
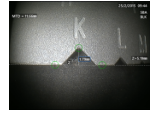
Measurement Accuracy Data

The measurement accuracy curves on pages 19–20 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



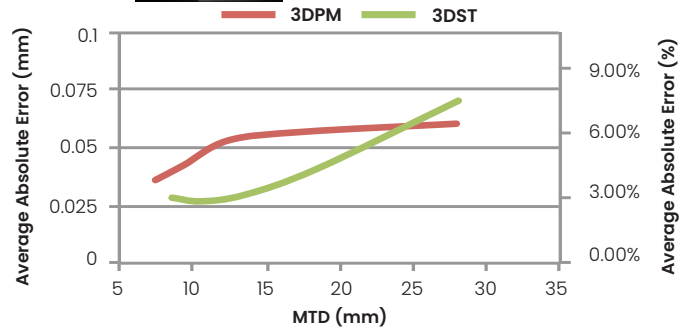
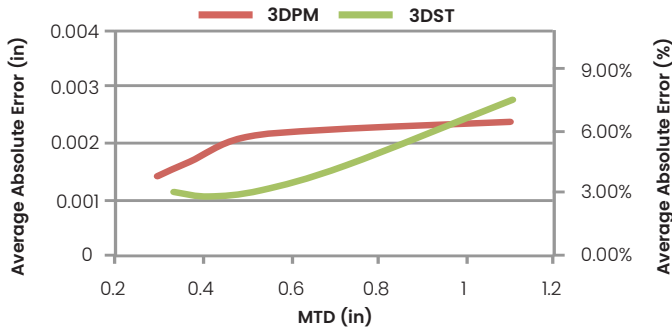
Pt-Line Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.071" (1.803 mm) Edge Ding Feature



Accuracy curve for length measurement of a crack.

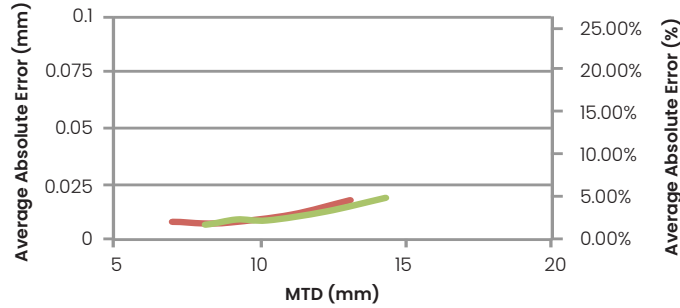
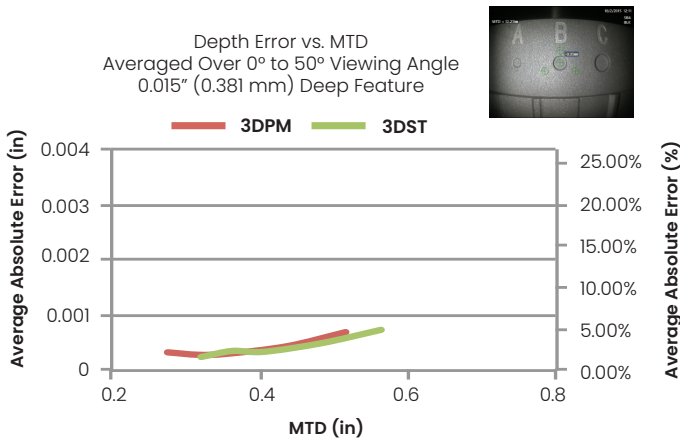
Accuracy curve for point to line measurement of an edge ding.

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

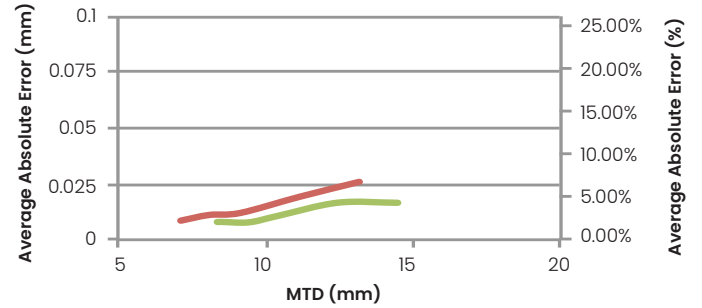
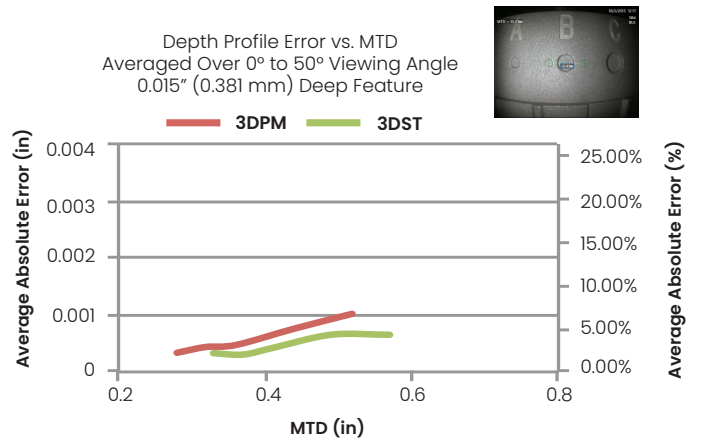


Accuracy curve for point to line measurement of a missing corner.

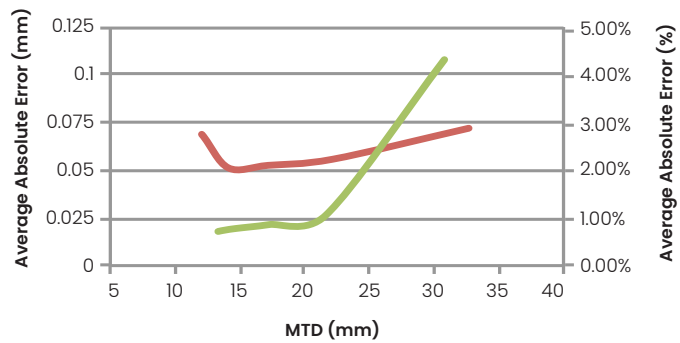
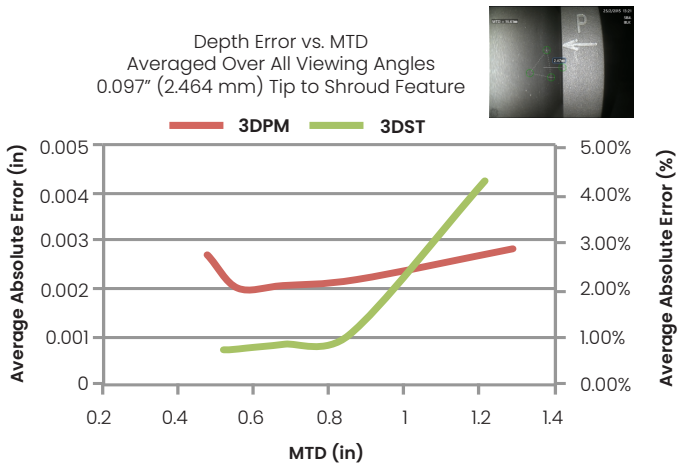
Note: Measurement Planes were not used in this testing but would likely improve the results on some features.



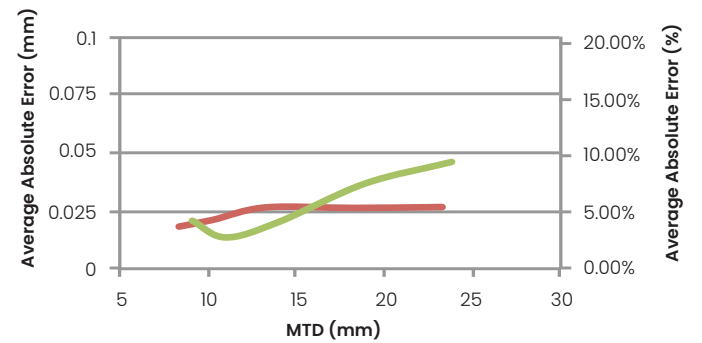
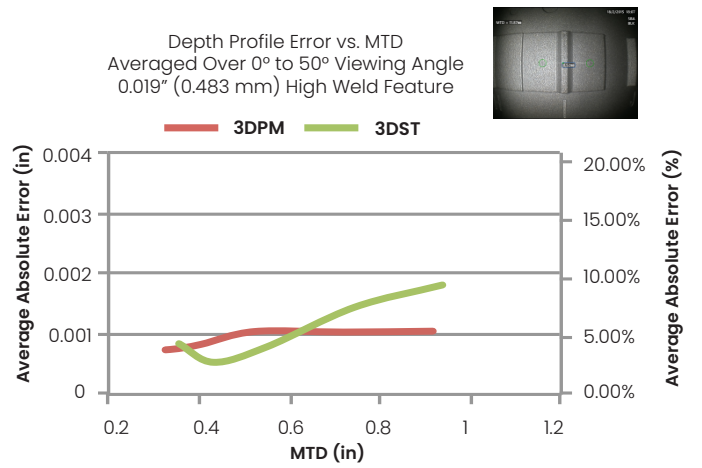
Accuracy curve for depth measurement of a pit or dent.



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	Black	105-FWD	8-250	(.31-9.84)
XL4TM61105SG	Blue	105-SIDE	7-250	(.27-9.84)
XL4TM61105FN-8651	Orange	105-FWD	3-120	(.12-4.72)
XL4TM61105SF	Green	105-SIDE	15-inf	(.59-inf)

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 6.2mm Tips

3D Phase Measurement Tips

PXTM6260FG	Black	60/60	4-80	(0.16-3.15)
PXTM6260SG	Blue	60/60	4-80	(0.16-3.15)

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)

Stereo and 3D Stereo use the same Optical Tip Adapters

Measurement Software Part Numbers

3D Stereo Measurement

MVIQ-3DPM

UG-3DPM

3D Phase Measurement

MVIQ-3DST

UG-3DST

Stereo Measurement

MVIQ-ST

UG-ST

Projected Plane Measurement

MVIQ-PPM

UG-PPM

Area Depth Profile

MVIQ-ADP

UG-ADP

Probability of Detection Software

MVIQ-POD

UG-POD

Blade Tip Clearance

MVIQ-BTC

UG-BTC

Dark Boost

MVIQ-DARKBOOST

UG-MVIQ-DARKBOOST

Upgrade

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 on which lines and spheres are 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 measurement setup and initiate and edit 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 and tip optics 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.

Auto-Repeat – Performs repetitive measurements with the click of a button (such as blade tip clearance).

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

Dark Boost – Dark Boost is a live video processing function which digitally brightens darker areas in scenes with bright foreground surfaces, or glare, without over-exposing or degrading the contrast of more uniform scenes.

Depth Assist – Feature wherein 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.

Image Brightness – As it relates to a video borescope is a combination of several components, not just available light

- For live video, the image brightness control adjusts the brightness set point for the camera's auto gain and exposure control processing
- For still images, the image brightness control digitally adds or subtracts an offset from the image's RGB values

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. Insight for where data can be pushed and remeasured by SMEs.

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 an 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.

Probability of Detection (POD) – *“POD is the probability that a flaw of a specific type will be detected by a given technique given the flaw exists in the material.” Bill Prosser, NASA*

You may ask, “What is Waygate Technologies’ POD on the Mentor Visual IQ (MViQ) VideoProbe™? And, how will it help me during inspections and indication analysis?”

In essence, POD is a combination of technologies which allow for the transformation of a white light image into one which will facilitate assessing the health of the visual surface, provide additional information about a surface's condition, and if & when an indication, or “flaw”, is detected these tools are available to provide greater precision and accuracy when deploying Real3D™ Phase and Real3D Stereo Measurement – both of which provide an XYZ pivotable point cloud for analysis.

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 which 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.

Surface Mask – One of several masks coloring pixels on a surface with various color gradients to indicate various surface contours or distances between cursors.

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.

3DPM Save Format –

- **PMap** – Original projected pattern images are embedded in the saved image file and fully re-processed to generate new 3D data when re-measurement is performed on the recalled image. Generally used for development and troubleshooting purposes.
- **ZMap** – Computed 3D surface data is embedded in the saved image file and used when re-measurement is performed on the recalled image. Gives smaller files than PMap and is recommended for most users.

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