LM2500 assist (v1.0)

Datasheet v2.0

Live and Still defect recognition in one product

Contents

1. Introduction

Waygate Technologies' now offers the ability to exploit artificial intelligence (AI) technology to provide customers a solution for detection and classification of defects directly on their Mentor Visual iQ borescopes **during live inspections**.

Based on the InspectionWorks ecosystem, analytics can be deployed to the borescopes, placing AI and assisted defect recognition (ADR) at the fingertips of the end-user.

By providing technology that assists with defect detections, inspections become faster, more objective and uptime of the asset is increased.

2. What is the LM2500 ADR Analytic?

Waygate Technologies has developed an ADR analytic based on Machine Learning. The analytic was trained using thousands of representative images from LM2500 gas turbine inspections. These have been "characterized" to teach a neural network about items or areas of interest.

Once the model is trained, it is deployed for inferencing to predict indications on live video and images.

The LM2500 ADR analytic was optimized to run on the Mentor Visual iQ borescope, but will also be available on the InspectionWorks cloud platform to enable analyses post- inspection.

It is designed to operate whilst the device is in both 'still' and 'live' states. They are two versions of the same analytic. Once both activated, the borescope has capability to detect and characterize the defect as it enters and leaves the field of view and then the operator is invited to enter the freeze frame or 'still' state in order to interact with the various indications before saving the image.

3. Warnings

Analytic applications are intended to assist the user whilst performing in-situ visual inspections. Results will vary depending on your application. State-of-art analytic applications are generally not 100% accurate and this analytic is no different. Do not rely on this analytic to detect all indications.

You, the user, are responsible for following the appropriate procedures and standards whilst undertaking in-situ visual inspections. Waygate Technologies USA, LP. cannot be held responsible for the accuracy nor outcome of any inspection. You must review this datasheet for intended use and limitations prior to use.

4. Prescribed usage

This analytic is based on ground truth data originating from the LM2500 gas turbine engine variant. It includes content from gas-washed surfaces spanning compressor, combustion and turbine stages. In order to enhance analytic robustness, images were captured from historical borescope inspections containing many incident angles and stand-off distances from the target component.

Indications have been classified using the following six characterizations:

1. Erosion

2. Rub

3. TBC loss
(Thermal Barrier Coating)

4. Dent/Nick

5. Tear

6. Crack

5. Accuracy metrics

	Identification		Identification + Classification	
	True Positive Rate	Precision	True Positive Rate	Precision
Total	84.6	82.7	80	77.8
Erosion	96.1	96	92.9	91.4
Crack	88	86.1	88	81.2
Rub	88.6	80.2	82.9	69.8
Dent/Nick	81.7	86.1	73.8	80.9
Tear	81.8	93.3	45.5	46.7
TBC Loss	72.7	68.5	67.8	66.1

Accuracy Metric Definitions:

$$\text{True Positive Rate} = \frac{\text{Indications Predicted Correctly}}{\text{Actual Indications}}$$

$$\text{Precision} = \frac{\text{Indications Predicted Correctly}}{\text{Total Indications Predicted}}$$

6. Dependencies

- Only operable on the Mentor Visual iQ (MViQ) Flame ("C" model) borescope
- Operating software version 3.65 or later
- Activated with LM2500ADR-S and LM2500 ADR-L Feature Keys (free trial or purchased)
- LM2500 assist-L analytic functions when MViQ is in the "live" state only
- •LM2500 assist-S analytic functions when MViQ is in one of the following two states:
  1. Freeze frame or 'FF' image
  2. Recalled image (originating from File Manager)

7. Operating instructions
(3.65 Mentor Visual iQ Release)

7.1 Activating/de-activating the analytic

1. Enter MViQ Global Menu and select "Analytics"

2. Review and accept disclaimer (can take about one minute after first boot only to enable initialization)

3. "Still Analytics" page is now displayed
   Select "LM2500 – assist-S" tile to toggle from "off" to "on"

4. Select "Live Analytics' tile
   Select "LM2500 – assist-L" tile to toggle from "off" to "on"

5. Press 'Done' softkey
   Both Analytics will now be started with on-screen message confirmation

Note the appearance of the analytics icon positioned in the status bar. This remains visible when any one or more analytic has been activated.

Repeat this procedure to de-activate the analytic albeit tap the tile from "on" to "off" during Steps 3 and 4.

## 7.2 Generating inferences

7.2.1 Live Image Function

Once activated (see Section 7.1), the analytic operates continuously whilst in the 'live' state.

Along with an indication count, "LM2500 assist-L v1.0" message is visible in the top right hand corner of the screen to indicate its operation. The message is retained within all saved output.

An on-screen Indication Detected Border alerts the user that the analytic has detected an anomaly.

Furthermore, a series of configuration options are also available to enable the user to customize a variety of displays when defects have been detected:

- As above but with indication bounding box

- As above but with defect characterization

- As above but with confidence value
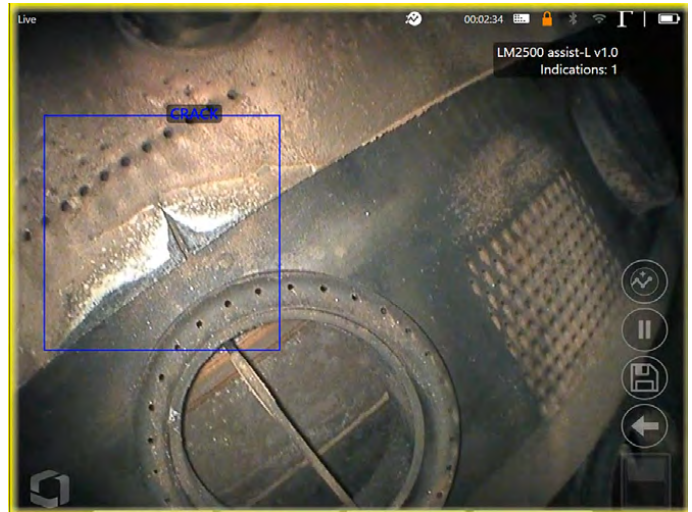
LM2500 ADR-L in operation. Note that i) Indication Detected Border is highlighted along with ii) indication box and iii) defect classification label are visible in this image

7.2.2 Freeze Frame Image Function

From the live video state, tap the touchscreen or press "Enter" hardkey to activate the Freeze Frame (FF) state. "FF" will now appear in the top left status bar.

LM2500 assist-S analytic will now activate and analyze the image. "LM2500 assist-S v1.0" will now be visible in the top right hand corner of the screen to indicate its operation
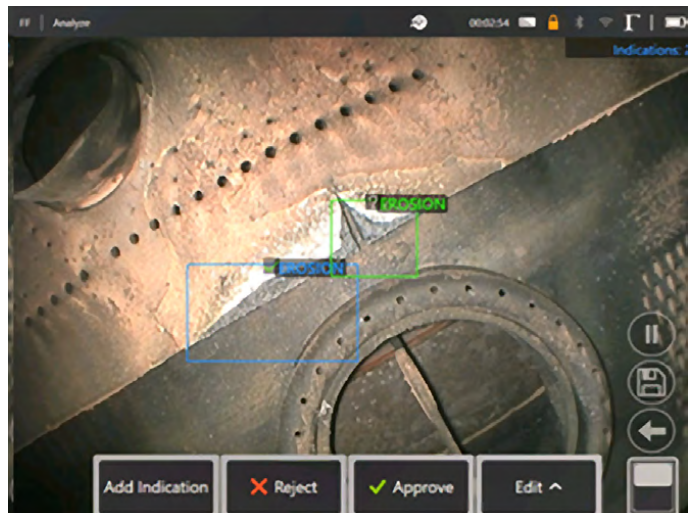
Initiate "Freeze Frame" to activate LM2500 ADR-S Analytic.

Now save image containing inferences or alternatively cycle through a series of options:

- Manually add an indication

- Accept or Reject each indication

- Edit the indication classification e.g. change from "erosion" to "crack"

- Edit the shape or size of the indication box

Go to section 7.3 for more details.

7.2.3 Recalled Image Function

Saved images can be analyzed at any time using the device. Ensure the analytic is activated (see Section 7.1) before then following these steps:

1. Tap the Global Menu shortcut on the touchscreen or press "Menu" hardkey to display the Global Menu page.

2. Select "File Manager" tile and then the desired image in order to load and display on screen.

3. Tap the softkey page button to present the second row of softkeys. Select "Analyze". softkey in order to process the image for indications.
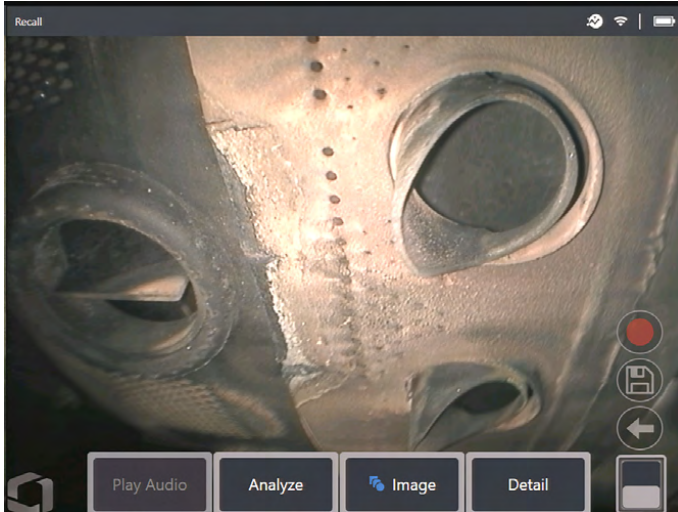
Recalled image showing "Analyze" softkey.

4. Now cycle through the indications to "accept", "reject" or alter any classification(s) as desired as per Section 7.2.2.

Go to section 7.3 for more details.

## 7.3 User functionality

7.3.1 LM2500 assist-L

This is the live analytic that only operates whilst the device is in the "live" state. It provides capability of displaying the presence of defects as they appear and move across the field of view.

Factory default is set to enable the presence of an Indication Detected (ID) border to alert the user that the analytic has detected an anomaly.
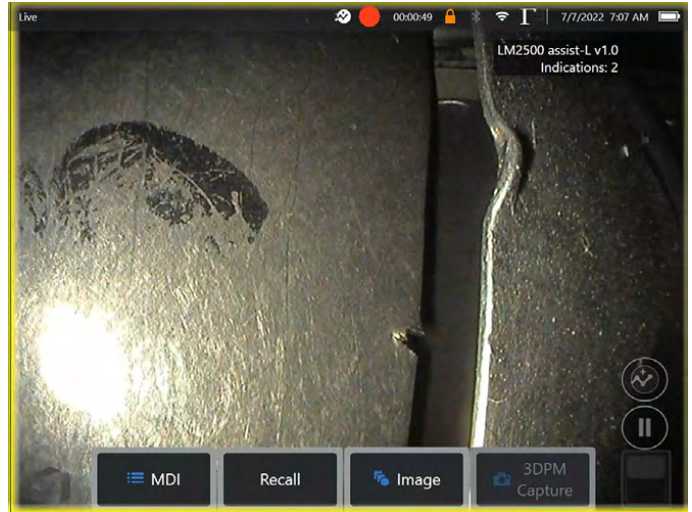
LM2500 assist-L activated showing the Indication Detected border highlighting presence of defects.

During this instance, it is possible to tap the 'peek' floaty button (highlighted in image below) and temporarily (10 second duration) view the location of the defect.
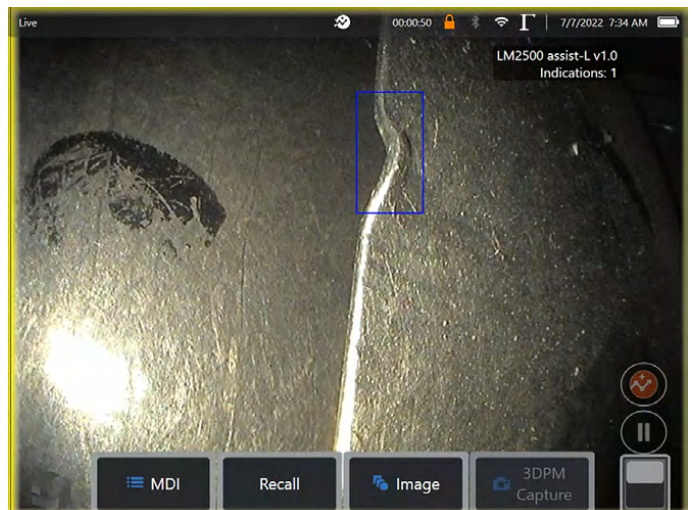
LM2500 assist-L activated showing the "peek" indication enabled to temporary visualize defect location.

A series of additional options are contained within the "Analytics (Live)" settings page. These enable the user to customize the view and present more information to the user during the live inspection.

• Indication bounding box – on/off
  This is the four-sided polygon that the analytic generates and places at the appropriate defect location

• Defect classification – on/off
  This is the text label associated with the indication bounding box. LM2500 assist-L analytic has classification capability

• Confidence value – on/off
  This is an additional text label to present a percentage indication of the analytics likelihood of how similar the prediction is to the ground truth

• Classification Filter
  This enables the user to remove specific defect classifications from being presented on-screen. Note: this functionality is also available with the LM2500 assist-S analytic
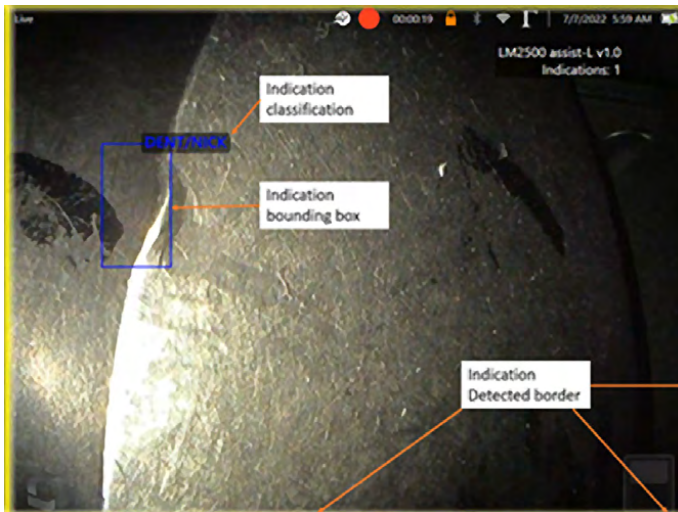

Example showing the automated appearance of various on-screen indicators to alert user presence of detect

7.3.2 LM2500 assist-S

This is designed to be operated in conjunction with LM2500 assist-L. Once the defect has been automatically detected, it is possible to then enter the Freeze Frame (FF) or "still" state and interact with all on-screen indications.

• Add Indication (manually)

• Accept – to agree and retain inference

• Reject – to disagree and disregard (not delete) inference

• Edit classification – to alter the defect category to another pre-determined type

• Edit indication – to alter the shape or size of indication

• Hide / Show confidence value

1. Tap or press "Enter" hardkey to cycle through any or all inferences whilst pressing "Accept" or "Reject" softkeys. Selecting 'Edit' also enables user to change the classification as required.

2. Here we have an example where many bounding boxes presented on-screen. The user has the choice to accept (indicated as green TICK) or reject (indicated as red CROSS) each one. Once completed, a temporary banner appears to indicate all bounding boxes have been reviewed.
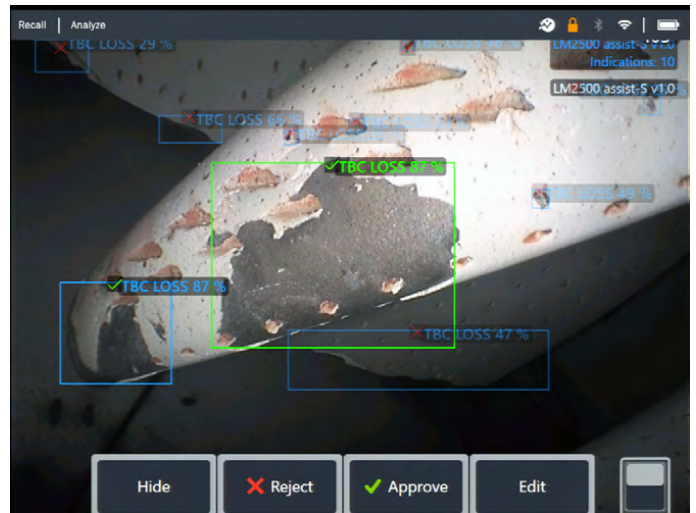
3. Once the image is saved and then subsequently recalled, only the accepted bounding boxes will be immediately visible. This image shows the two bounding boxes that were "accepted." The remaining bounding boxes remain present but "hidden" within the file.

   It is possible to adjust, amend or undo these adjustments at anytime once the image has been saved. No data is lost or erased
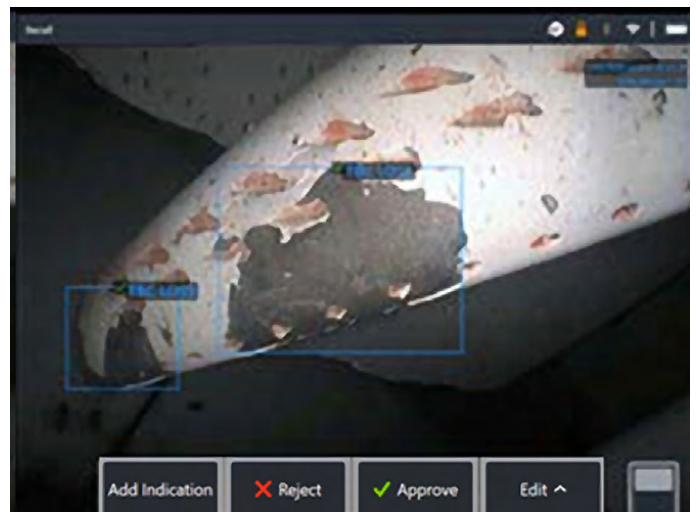

4. Confidence Values provide a percentage indication of the analytics likelihood of how similar the prediction is to the ground truth. 'Off' is the factory default setting.

To show "Confidence Value" navigate to the 'Settings' menu and select 'Analytics (Still)' as shown below.

Tap the toggle or press 'Enter' hardkey to activate this feature.
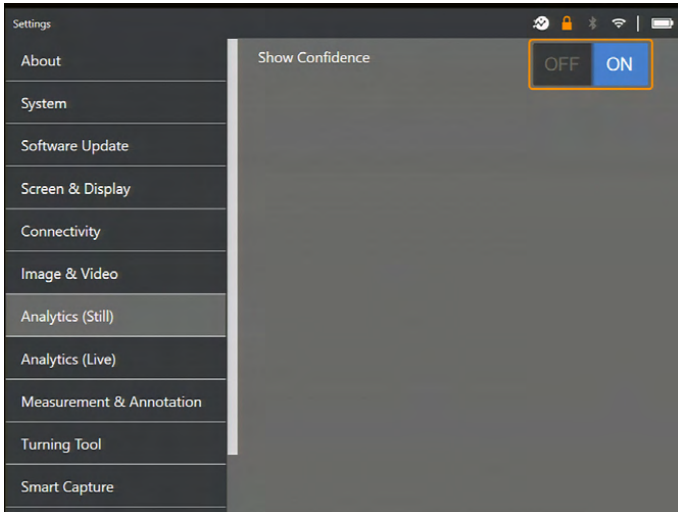
The classification filter is a useful feature to enable the operator to focus attention on detecting certain defect classifications only. This is available in both live and still analytics. during inspection of components for particular defects such as cracks and other classifications such as TBC loss is disregarded.
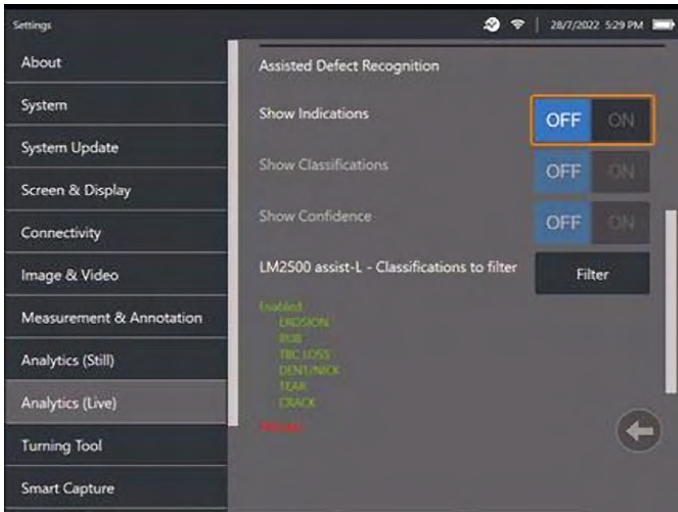
Now recall image and select "Analyze" softkey or activate freeze frame (FF) to generate the inference. All bounding boxes will now be presented with the Confidence Value denoted as a percentage value.

7.4 Review / reanalyze

Saved images containing inferences from an analytic can be:

• Reviewed - using saved inferences from original analysis, or

• Reanalyzed - using the analytic activated on the handset

7.4.1 Reviewing saved image(s)

It is possible to review all bounding boxes contained within a saved file from any MViQ Flame handset. The LM2500 assist-S

does not need to be activated to enable this feature since all original data is retained within the file.

1. This recalled image is displaying two bounding boxes although the total number of indications is three.
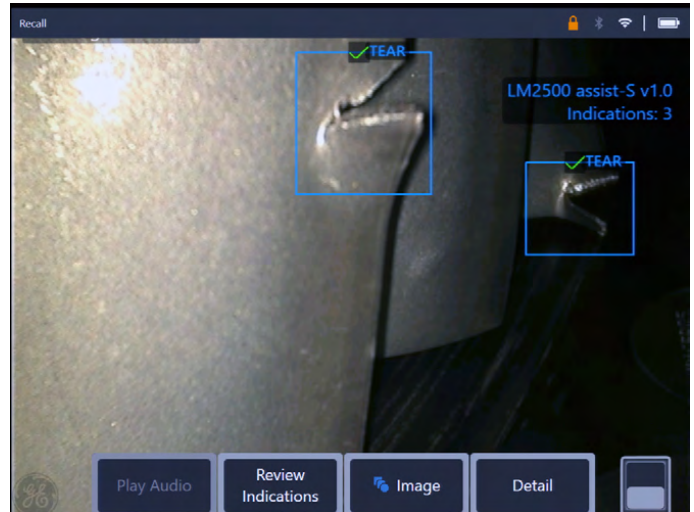
Note that no Analytic is activated – Analytics icon on status bar is not visible.

2. Select 'Review Indications' softkey to present all original indications i.e. making visible any 'Rejected' or unreviewed bounding box(es).
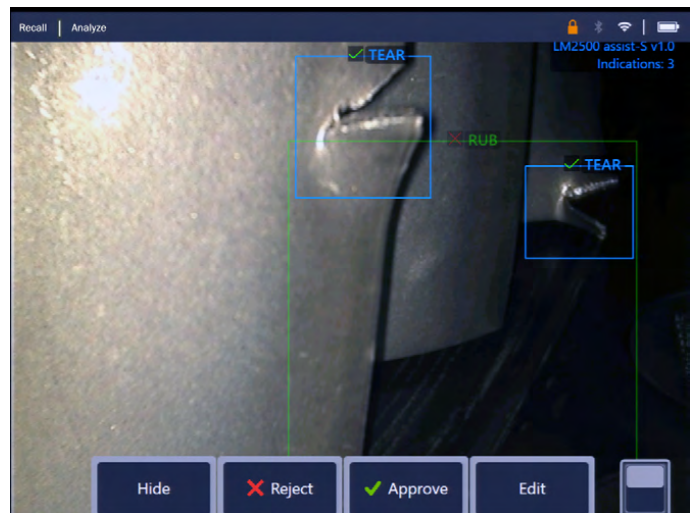
Use this function to check correct assignment of all detected indications using the original data captured within the file.

7.4.2 Reanalyzing saved image(s)

It is possible to reanalyze all bounding boxes contained within a saved file.

To enable this function, ensure the LM2500 assist-S analytic is activated (see Section 7.1). This feature enables the current activated analytic to reanalyze the loaded image.
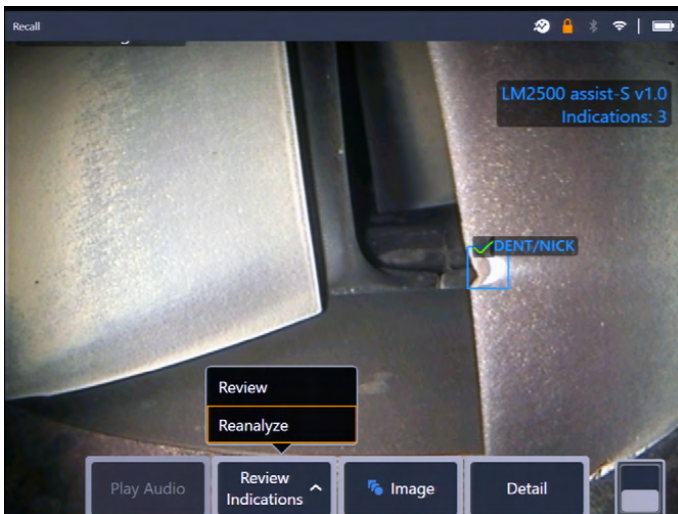
This is applicable if a different analytic version is now in-use.

1. This recalled image is displaying one bounding box although the number of indications displayed is three.
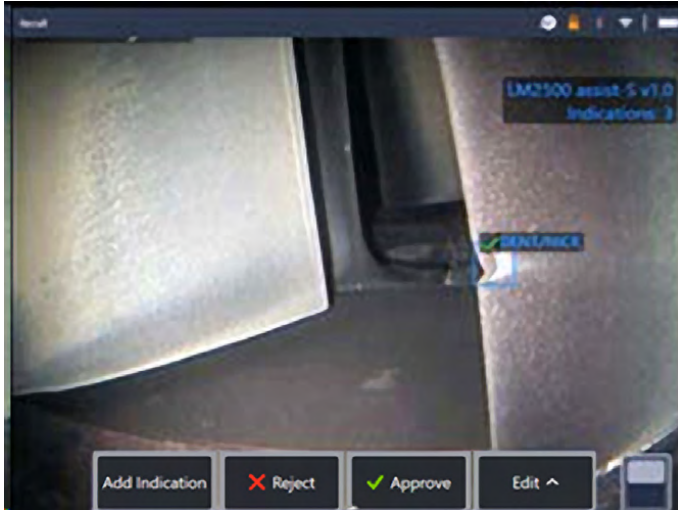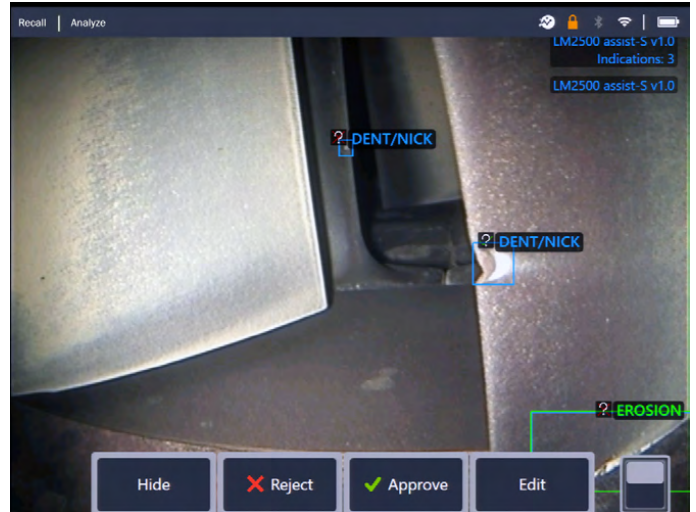

Note that Analytic is activated – icon on status bar is visible.

2. Select 'Review Indications' softkey and then "Reanalyze."

3. The handset overwrites any prior assignments e.g. acceptance or rejections and displays the output from the activated analytic.

Note all inferences are now visible and the user is invited to review as appropriate.

8. Technical support

Technical Support contact information follows:

Global Phone: 1-866-243-2638
(Mon – Fri 8:00 AM – 5PM E.S.T. North America)

Waygate Technologies Remote Service email:
RemoteService@BakerHughes.com

Please also provide the following important details:
• Handset model number
• Handset serial number

9. Revision history

Revision number	Date issued	Reason
1	December 2021	Initial launch
2	July 2022	Introduction of Live-ADR and updated Still-ADR functionality

10. Frequently Asked Questions (FAQs)

Q: How do I obtain this ADR analytic?

A: A free 90-day trial should be activated after installing 3.65 software. After that, contact your local Waygate Technologies sales representative, or visit www.waygatetech.com/MentorVisualiQ.

Q: Is it possible to create other analytics designed for other engine variants; other components; or other defect types?

A: Yes. Waygate Technologies are committed to delivering Inspection Solutions to the inspection industry. Please contact your local Waygate Technologies sales representative to discuss your needs.

Q: What is a 'live image" ADR analytic?

A: It is a Computer Vision model that predicts the presence of; and categorizes the detected indications contained within a "live" image. The model was trained on thousands of images derived from a dataset of images captured from videoscopes used during actual in-situ inspections.

A: LM2500 assist-L is a different version of the same analytic used for LM2500-S. It is optimized for live inspection workflows.

Q: What is a "still image" ADR analytic?

A: It is a Computer Vision model that predicts the presence of; and categorizes the detected indications contained within a "still" or "freeze frame" image. The model was trained on thousands of images derived from a dataset of images captured from videoscopes used during actual in-situ inspections.

A: LM2500 assist-S is a different version of the same analytic used for LM2500-L. It is optimized for "still" or freeze frame inspection workflows.

Q: Why should I consider using an ADR analytic?

A: Improves consistency and reliability of inspection tasks by leveraging Computer Vision technology to assist the trained Inspector in conducting the visual inspection.

A: Reduces the probability of missing indications on critical turbomachinery components.

A: Increases the overall quality of inspection output.

A: Provides automatic annotation for the user to simply approve.

Q: Which engine components is it designed to operate on?

A: Gas turbine aerofoil within the LM2500 Compressor and Turbine systems

A: LM2500 combustion chamber hardware

A: Note that LM2500 is an aeroderivative of the CF6-6 aero gas turbine

Q: How was this ADR analytic validated?

A: Waygate Technologies has validated this analytic on 405 images from LM2500 inspections based on 4273 images within the training dataset. This analytic has not been formally validated by the LM2500 OEM.

A: See section 5.

Q: What does the confidence value indicate or infer?

A: This index provides an indication of how similar the prediction is to the ground truth the analytic was trained on. It indicates the likelihood of a correct prediction but is not the probability of correct predictions.

Q: Which tips or Optical Tip Adapters (OTA's) are needed for this ADR analytic to function?

A: The analytic is not currently dependent on tips or Optical Tip Adapters.

Q: Will this ADR analytic work for all MViQ probe diameter options? i.e. 4mm, 6mm and 8mm

A: Yes

Q: What type of indications is it designed to detect?

A: Erosion (which can sometimes be classed as "oxidation"); Rub; TBC loss; Dent/Nick; Tear; Crack.

Q: Will it measure indications?

A: No, these analytics do not have measurement capability. However, Real3D measurement technology can be used to measure indications that have been found by the analytic.

Q: Will this ADR analytic work on the MViQ "Grey" handset?

A: No.

Q: Can I use this ADR analytic whilst inspecting other gas turbine variants?

A: Yes. Waygate Technologies is unable to guarantee its performance or even applicability to other gas turbine variants but visual appearances of gas turbine components are often very similar.

Q: Does the MViQ need to be digitally connected in some way e.g. to the Internet or some other device in order to work?

A: No. The analytics operate entirely standalone within the device.

Q: Can I use the ADR analytic post-inspection on the MViQ device?

A: Yes. This ADR "still" analytic can operate on recalled images within the MViQ "Flame" handset. Such images can be: those that have either been previously processed using this analytic; or raw/unprocessed images. Inferences can be generated and subsequently saved for presentation or inclusion into the inspection report.

Q: Can this ADR analytic be accessed and operated from within Waygate Technologies Inspection Manager software?

A: No, but this functionality is planned within a future release.

Q: Do Analytics operate in conjunction with other Mentor Visual iQ features?

A: Image storage – Analytic results are stored in the still image file. This information is normally hidden when viewing jpg images on a standard consumer device like a laptop or phone. However when viewed on the MViQ borescope, the analytic results may be adjusted, hidden, or rejected. This will also be possible if accessing the file from Inspection Manager software and InspectionWorks cloud platform in the near future.

A: MDI – Analytics can be "prescribed" by an MDI template. At the time of writing, the MDI builder tool is not able to add analytics to an MDI template in a graphical fashion. The MDI template must be edited for you by Waygate Technologies. This enables the user to have analytics activate at the appropriate stage(s) automatically. Please contact Waygate Technologies support for further information.

11. Glossary

AI (Artificial Intelligence)	The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages
Analytic	A mathematical model based on computer vision logic designed to create an inference or output
Characterization	The ability to add or label images with data enabling analytics to generate inferences
Gas-washed surfaces	Surfaces within the gas turbine directly exposed to air used to generate propulsion or thrust
Ground truth	Characterized data used to train the analytic
Inference	The displayed output of an analytic
Bounding box	The area highlighting the presence of an indication

Baker Hughes

waygate-tech.com