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RapidArc QA Test Procedures for TrueBeam

TrueBeam
TrueBeam STx
Edge Radiosurgery System

CE 0086

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Document ID	P1010551-001-A
Document Title	*RapidArc QA Test Procedures for TrueBeam*
Abstract	This document provides information and test procedures for the TrueBeam system and is intended solely as a supplemental document. For complete information concerning components, safety instructions, installation, maintenance, troubleshooting, etc., refer to the applicable Varian product Operator's Manual. This document does not replace the Varian Operator's Manual. Carefully read all instructions prior to use. Observe all contraindications, warnings and precautions noted in these instructions. Failure to do so may result in patient and/or user complications. This publication is the English-language original.
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- International Classification of Diseases for Oncology, (ICD-O) 3rd edition, Geneva, World Health Organization, 2000.

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- International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10). Vols 1–3, Geneva, World Health Organization, 1992.

CAUTION: US Federal law restricts this device to sale by or on the order of a physician.

Contents

Chapter 1 Introduction

Purpose

Note: *This document is not intended to be used as an acceptance procedure to define RapidArc® specifications for Clinical use. Typical results are provided as a guideline for the tests, but the users must determine the Clinical tolerances appropriate for their equipment. The IPA-HT is used by Varian installation and upgrades team to perform all tests required for acceptance.*

The purpose of this document is to provide a high level description of the RapidArc QA files as well as simple instructions for using them. This document and its accompanying files are not and should not be considered as any form of recommendation from Varian on what constitutes a complete RapidArc machine QA program.

For a discussion on RapidArc machine QA, the reader is encouraged to refer to: Ling et al., *Commissioning and Quality Assurance of RapidArc™ Radiotherapy Delivery System,* Int. J. Radiation Oncology Biol. Phys., Vol. 72, No. 2, pp. 575–581, 2008.

The RapidArc QA files described in this document are designed after the work in this paper and can be used to reproduce similar tests.

Scope

This document and its accompanying RapidArc QA files are provided for Varian linear accelerators equipped with either the 120 MLC—Radiation Oncology Version or the HD 120—High-Definition MLC and RapidArc.

NOTICE: The test plans are designed for 6MV X-ray beam and a dose rate of 600MU/min. Changing the dose rate may change the desired test parameters since changing the dose rate will result in different gantry and MLC leaf speeds for Tests 2 and 3.

Managing the Plans

This document describes acquisition of test images using File mode on TrueBeam® systems. These procedures are appropriate for infrequent performance of this test sequence, but may be cumbersome to perform on a regular basis. The RapidArc QA files can also be delivered, and images acquired, using a record and verify system. Verification plans can be delivered in Plan QA mode by selecting **QA** from the Queue (rather than **Treat**). QA mode opens the verification plan for delivery and image acquisition. The plans can be delivered multiple times, images acquired, and all acquired images saved to the database.

Imaging and Evaluation Tools

The procedures described in this document are designed to be performed with the aS1000 or aS1200 Portal Vision MV imager using Dosimetry imaging. Customers who do not have the Dosimetry imaging license, should use film or other devices to perform this procedure.

All image acquisitions are performed using the Dosimetry Image mode. This mode requires a Dosimetry calibration as described in your MV imager documentation.

Note: *For Portal Dosimetry customers, Dosimetry Image calibration is also used for Portal Dosimetry pre-treatment QA measurements. A qualified medical physicist should determine the appropriate calibration settings for both Portal Dosimetry and RapidArc QA.*

This document describes evaluation of the images using tools provided in the TrueBeam Imaging workspace. Users of the ARIA OIS RO suite of applications may perform the same evaluations using the Offline Review workspace.

Note: *Accurate evaluation of the images requires at least 5 digits of precision for the histogram values. Using fewer than 5 digits of precision may result in rounding of values, and therefore inaccurate results. When using ARIA OIS RO, use only the Offline Review workspace to perform the evaluation.*

Note: *For non-ARIA users, all evaluations must be performed using the tools provided in the TrueBeam imaging workspace. You must perform the analysis* ***during the image acquisition process****; you cannot perform the evaluations after the images are saved.*

NOTICE: The plans provided are Verification plans, which must be delivered in Machine QA mode. The following procedures require TrueBeam 2.0 or greater to properly evaluate test images using Machine QA mode.

NOTICE: Calibration of the accelerator's dosimetry monitoring system should be performed following the guidance provided in CTB-GE-228. Dose calibration that significantly exceeds 1.0 cGy/MU at Dmax may stress the dosimetry system beyond its design capabilities, resulting in inaccurate or erratic results of the following tests.

Visual Cues

This publication uses the following visual cues to help you find information:

WARNING: A warning describes actions or conditions that can result in serious injury or death.

CAUTION: A caution describes hazardous actions or conditions that can result in minor or moderate injury.

NOTICE: A notice describes actions or conditions that can result in damage to equipment or loss of data.

Note: *A note describes information that may pertain to only some conditions, readers, or sites.*

Tip: *A tip describes useful but optional information such as a shortcut, reminder, or suggestion, to help get optimal performance from the equipment or software.*

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The my.varian.com website provides contact information, product documentation, and other resources for all Varian products.

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1. Go to http://my.varian.com.
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3. Choose an option:
   - If you do not already have an account, click **Create New Account** and follow the instructions. Establishing an account may take a few days.
   - If you have an account, go to the next step.
4. Enter your user name and password.
5. Browse the information and then click the link that corresponds to what you want to do:
   - Fill out and submit a support request.
   - Find documents. Online documents in PDF format include customer technical bulletins (CTBs,) manuals, and customer release notes (CRNs).
   - Send an e-mail to Varian support. You can browse for international e-mail addresses and telephone numbers by geographic area, and for oncology-specific contacts such as for brachytherapy.
   - Find parts and services by geographical area.

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Ordering Documents by Phone

You can order documents by phone by calling Varian Medical Systems support.

Location	Telephone Number
North America	+ 1 888 827 4265 (Press 2 for parts)
Global	Call your local Varian office.

Chapter 2 List and Description of RapidArc QA Files

Section 1

The test files described in this section are discussed in the Pre-requisites for RapidArc QA section of Ling et al.

1. Test 0.1: DMLC Dosimetry

   DMLC dosimetry — Measure the output at gantry angles 0°, 180°, 90° and 270° for a 4×10 cm DMLC field with a 0.5 cm slit to test the effect of gravity on leaf position and Clinac dosimetry system.

   - File for 120 MLC—Radiation Oncology Version: **T0.1_Dosimetry_M120.dcm**
   - File for HD 120—High-Definition MLC: **T0.1_Dosimetry_HD120.dcm**

2. Test 0.2: Picket Fence test versus gantry angle

   Picket fence test at stationary gantry angle — for subsequent comparison with tests during RapidArc.

   - File for 120 MLC—Radiation Oncology Version: **T0.2_PicketFenceStatic_M120.dcm**
   - File for HD 120—High-Definition MLC: **T0.2_PicketFenceStatic_HD120.dcm**

Section 2

The files described in this section correspond to Tests 1, 2, and 3 in Ling et al. All plans have been adapted to the TrueBeam platform. The plans may not match exactly to the original publication, but are intended to meet the original purpose of the tests. For detailed descriptions of the tests, their intent, and expected results, refer to the paper.

1. Test 1.1: Picket Fence test during Rapid Arc

   Picket fence test during RapidArc — to test the effect of gantry rotation on the MLC positional accuracy.

   - File for 120 MLC—Radiation Oncology Version: **T1.1_PicketFenceRA_M120.dcm**
   - File for HD 120—High-Definition MLC: **T1.1_PickectFenceRA_HD120.dcm**

Note: *If the portal imager is used, it is not possible to acquire an image similar to Figure 3 in Ling et al. That image was acquired with a film. It is possible to add images from tests 0.2 and 1.1 to replicate the double exposed film.*

2. Test 1.2: Picket Fence test during RapidArc with intentional errors

   Picket fence test during RapidArc with intentional errors — to demonstrate that test 1.1 can detect sub-millimeter errors during rapid arc.

   - File for 120 MLC—Radiation Oncology Version: **T1.2_PicketFenceError_M120.dcm**
   - File for HD 120—High-Definition MLC: **T1.2_PicketFenceError_HD120.dcm**

3. Test 2: Accurate control of Dose Rate and Gantry Speed during RapidArc delivery

   The Test 2 files correspond to the procedure described in Chapter 3 Image Acquisition and Evaluation of Test 2: Dose Rate – Gantry Speed Test.

   - File for 120 MLC—Radiation Oncology Version: **T2_DoseRateGantrySpeed_M120_Rev01.dcm**
   - File for HD 120—High-Definition MLC: **T2_DoseRateGantrySpeed_HD120_Rev01.dcm**

4. Test 3: Accurate control of Leaf Speed during RapidArc delivery

   The Test 3 files correspond to the procedure described in Chapter 4 Image Acquisition and Evaluation of Test 3: MLC Leaf Speed Test. This test uses 4 combinations of leaf speed and dose-rate to give equal dose to four strips in a RapidArc field.

   - File for 120 MLC—Radiation Oncology Version: **T3_MLCSpeed_M120_Rev01.dcm**
   - File for HD 120—High-Definition MLC: **T3_MLCSpeed_HD120_Rev01.dcm**

Note: *The arrangement of leaf speeds for this test is changed with respect to the article in order to allow delivery of the test on a clinical system. For a beam with a dose rate of 600MU/min, the leaf speeds are as follows: 1.7 cm/s, 2.0 cm/s, 1.0 cm/s, and 0.5 cm/s.*

Chapter 3 Image Acquisition and Evaluation of Test 2: Dose Rate – Gantry Speed Test

Dose Rate—Gantry Speed Test Procedure

Note: *This section of the procedure uses the MV imager to acquire test images. The same evaluation can be done with different measurement devices, such as film.*

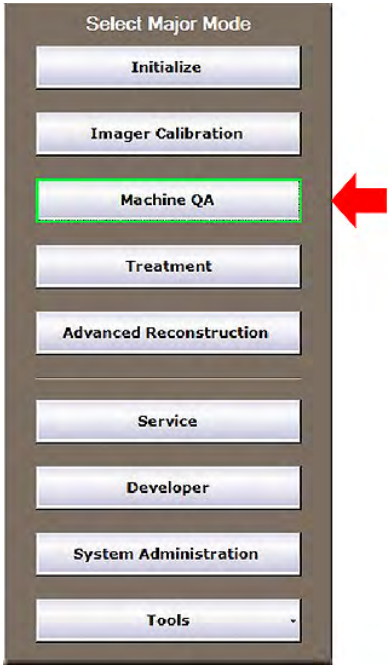
Note: *The MV imager needs to be calibrated for the Dosimetry Imaging Technique for the energy mode used in the RapidArc QA plans.*

Note: *The MV imager should be positioned so that the lateral and longitudinal positions are equal to 0. Images acquired in the following example were acquired at 100 cm source-to-image plane distance.*

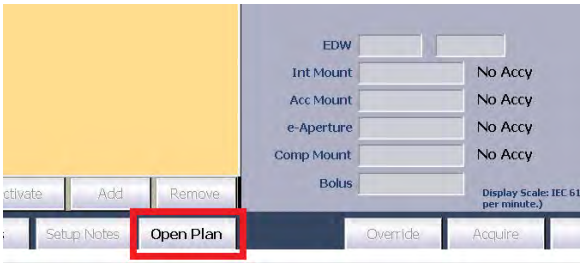
1. Extract the RapidArc QA files to a location accessible from the treatment console.

Note: *Typically, the I: drive is used to store files that will be accessible from the TrueBeam Treatment console.*

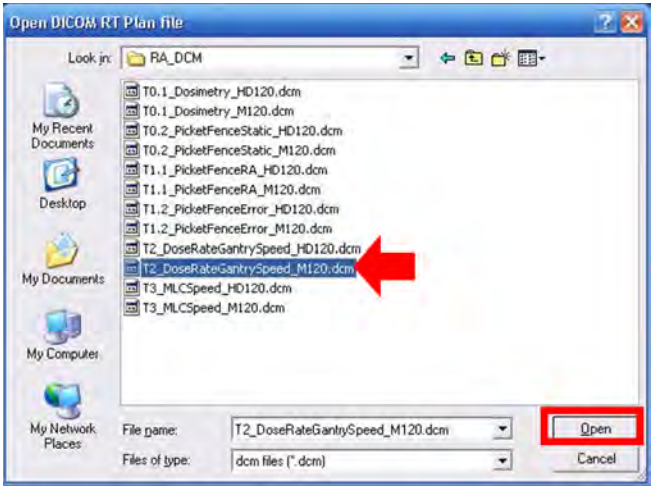
2. At the TrueBeam workstation, log in to Machine QA mode.



3. Select **Open Plan** to open the DICOM RT file with the test plan.



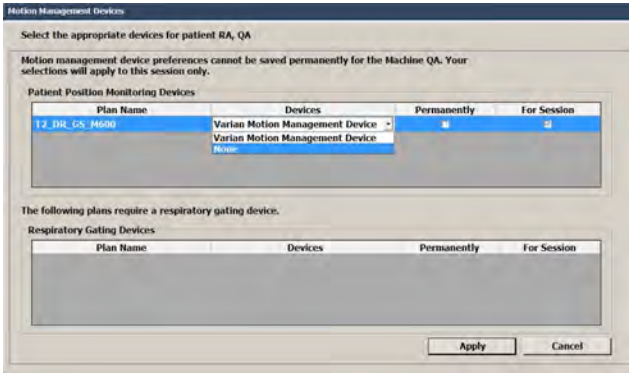
4. Navigate to the folder with DICOM RT files.
5. Select the file with the test for the MLC model used, and click **Open**.



Note: *The test files do not contain Second Channel Integrity Check (SCIC) data. The treatment application may issue a warning to confirm changes before using the plan. If a warning is issued, enter your login credentials and click Continue.*

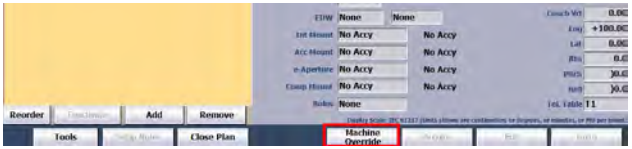
The imaging application may warn you that the loading of RT Structure set and/or RT images failed. This is because test plans do not contain images or structure sets, but may reference them.

If the installation has Advanced Imaging Auto Beamhold, the Motion Management Devices window appears so that you can select a device for the procedure.



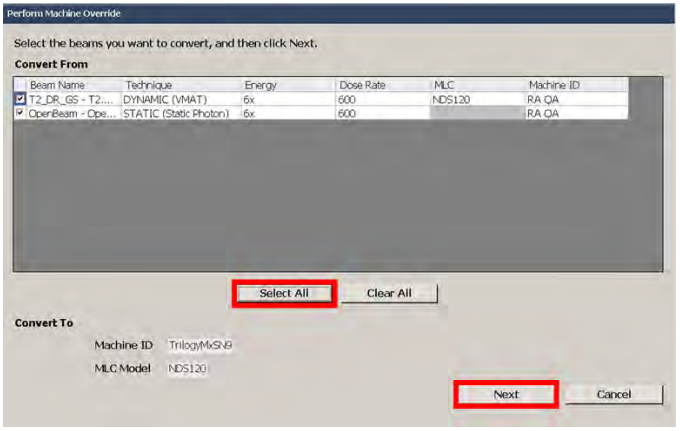
6. Expand Devices, select **None**, and click **Apply**.

7. Click **Machine Override**.



8. Enter your username and password and click **OK** to authorize the Machine Override.

9. Click **Select All** to override all of the fields and click **Next**.



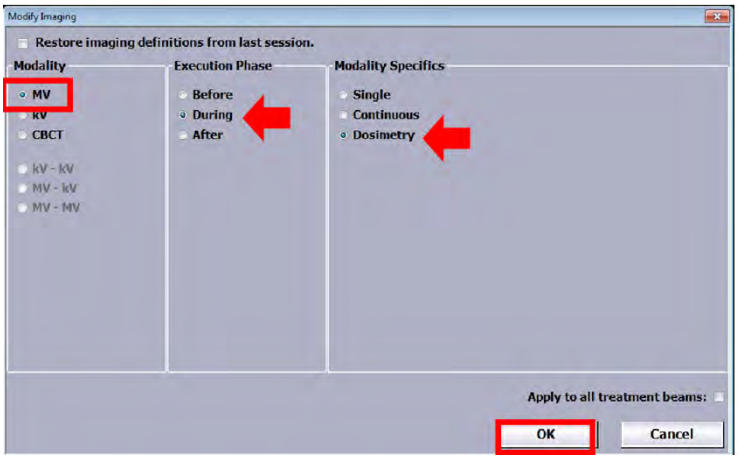
10. Confirm the energy of the fields and click **Convert**.

A summary window informs you whether the override was successful.

11. Click **Done** to close the summary window.
12. Highlight the first field and choose **Add** > **Add Imaging**.

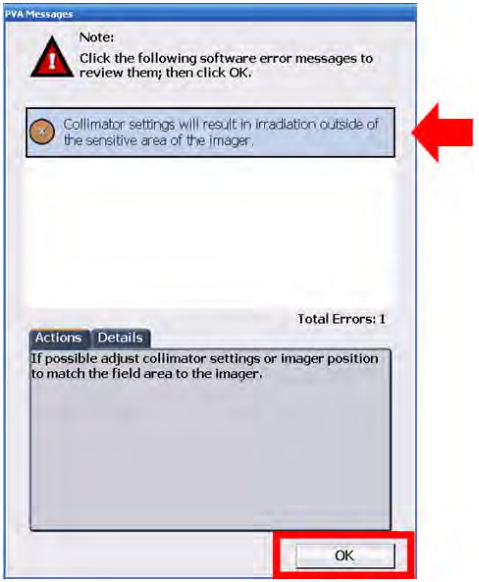
The Modify Imaging window appears.

13. Select the following options and then click **OK**:
    - Modality: MV
    - Execution Phase: During
    - Modality Specifics: Dosimetry



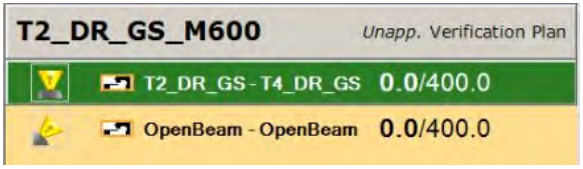
If the panel is still at position where the area outside of the active imager is irradiated, then the imaging application warns that the collimator setting will result in irradiation of the sensitive area of the imager.

14. Select the message and click **OK** to close the message dialog.



15. Verify that **Imager VRT** is set to 0; change it if it is not, and then click **OK** at the bottom of the screen.

16. Repeat steps 12 to 15 to add imaging procedures to the second field.
17. Highlight the first field.



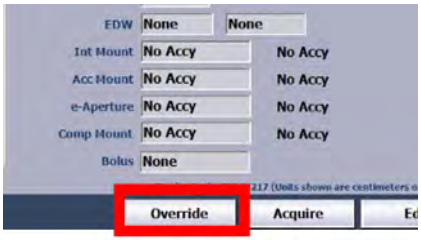
18. At the control console, click **Prepare**.
    A clearance caution message appears.
19. Click **OK** to clear the message and continue.
20. Ensure that the couch is retracted.

21. Move the gantry and imager axes to position.

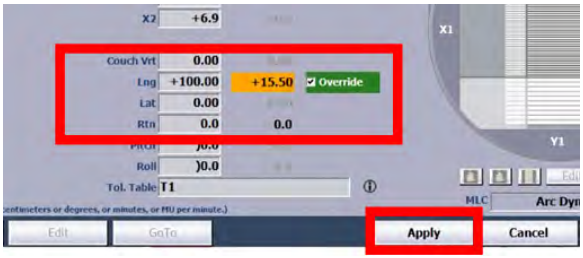
    To avoid possible collisions, retract the couch and check to ensure clearance of the rotating gantry.

22. Override couch positions, if required; otherwise, skip to the next step.

    a. Click **Override**.



    b. Select the couch axes to override and click **Apply**.



    c. Enter your user credentials to authorize the Override.

23. When all of the interlocks clear, press **MV Ready**, and then **MV Beam On** to deliver the beam.

24. Repeat steps 18 to 23 to deliver the beam and acquire images for the remaining fields in the plan.

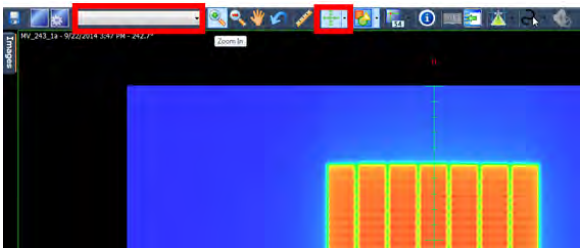
25. Select the first field.

The acquired image will display in the Imaging application.

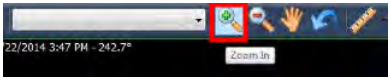
26. In the toolbar, click **Show/Hide Reference Image** to hide the reference image.

    Alternatively, you can hide the image by maximizing the view with the acquired image.

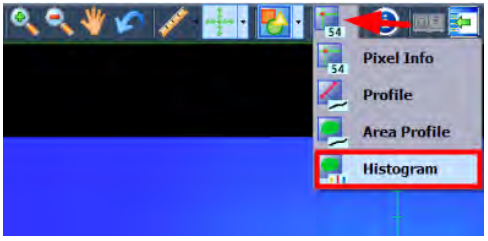
27. Make sure the Graticule is enabled and that no filter is selected.



28. Select the **Zoom In** tool and zoom in on the image.



29. Select the **Area Histogram** tool to enable the Area Histogram.

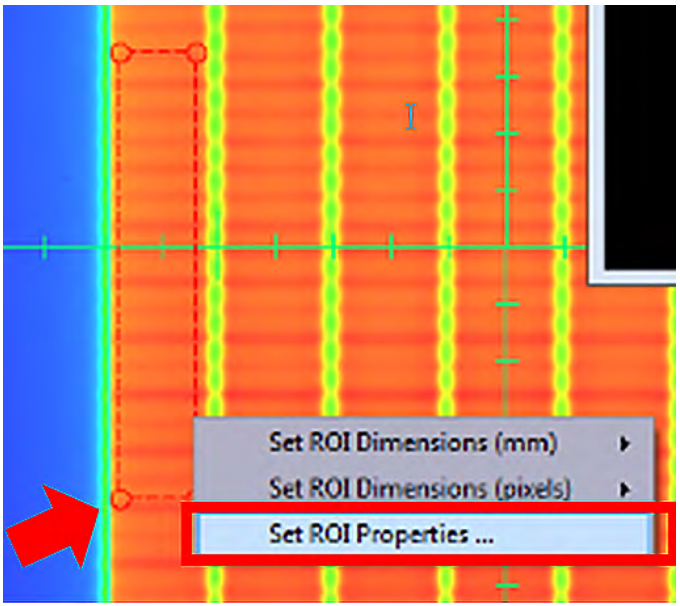


30. Draw a region of interest (ROI) on the image.

    The Histogram window appears.

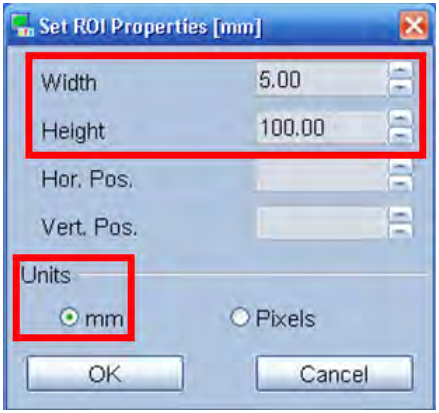
31. Right-click the histogram and select **Show Statistics** from the context menu.

32. Right-click a corner of the ROI border and select **Set ROI Properties** from the context menu.



The ROI Properties dialog box appears.

33. Set the following properties, and click **OK**:
    - Unit: mm
    - Width: 5mm
    - Height: 100mm

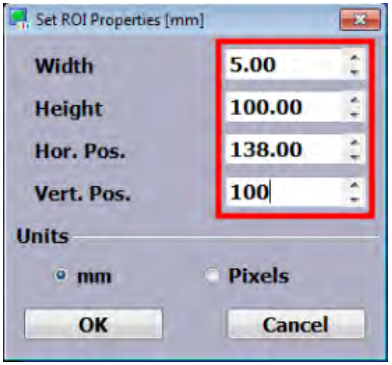


34. Center the ROI within the first vertical band by setting the horizontal and vertical positions for Band 1 (see table) and clicking **OK**.

The ROI should be centered on the graticule horizontal axis and centered within the band on the graticule vertical axis.

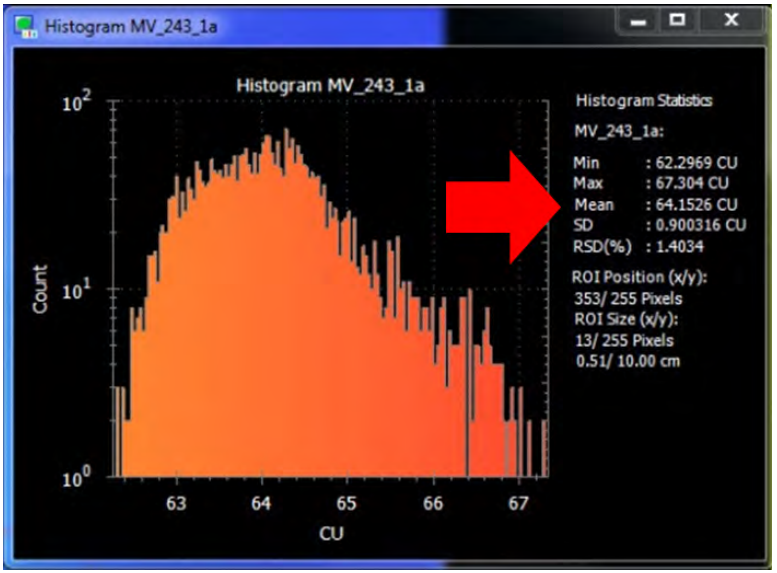
Band	Center of Band (Graticule)	ROI Hor. Pos.	ROI Vert. Pos. (aS1000 Imager Configurations)	ROI Vert. Pos. (aS1200 Imager Configurations)
1	−6 cm	138.0 mm	100 mm	150 mm
2	−4 cm	158.0 mm		
3	−2 cm	178.0 mm		
4	0 cm	198.0 mm		
5	+2 cm	218.0 mm		
6	+4 cm	238.0 mm		
7	+6 cm	258.0 mm		

The image below shows ROI properties for an aS1000 imager configuration. For an aS1200 configuration Vert. Pos. should be 150 mm.

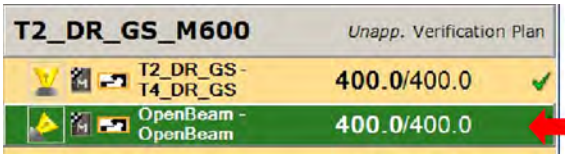


35. Note the mean pixel value indicated by the histogram statistics.

    You will use the value for calculations in a later step.



36. Repeat steps 34 to 35 for Bands 2 through 7 (see table in step 34).
37. Select the open beam.



The acquired image displays on the Imaging screen.

38. Use the **Zoom In** tool to zoom in on the image.
39. Repeat steps 29 through 36 to record open field pixel values at the same ROIs as the test image.
40. Calculate the corrected reading at all ROIs, using the following formula:

$$R_{corr}(x) = \frac{R_{DR-GS}(x)}{R_{Open}(x)} \cdot 100$$

Where:

- $R_{corr}(x)$ is the normalized Mean pixel value at the same ROI in the RapidArc field
- $R_{DR-GS}(x)$ is the Mean pixel value at a given ROI in the RapidArc field
- $R_{Open}(x)$ is the Mean pixel value at the same ROI in the open field

41. Calculate the deviation of each ROI using the following formula:

$$diff(x) = \frac{R_{corr}(x)}{\bar{R}_{corr}} \cdot 100 - 100$$

Where:

$\bar{R}_{corr}$ is the average of $R_{corr}(x)$ for all seven strips.

Machines using these plans will typically achieve numbers below 3% for each $diff(x)$.

42. Calculate the average of the absolute value of all $diff(x)$ values:

$$Diff_{abs} = \overline{|diff(x)|}$$

Machines using these plans will typically achieve numbers below 1.5% for $Diff_{abs}$.

Note: *The typical values presented here are not Varian specifications. Typical results are provided as a guideline for the tests, but the users must determine the Clinical tolerances appropriate for their equipment.*

43. In the Treatment application, click **Close Plan**.

Images are saved in either the source folder, or in the `\\MyServer\VA_TRANSFER\TDS\MachineID\Treatment\` folder if the plans were opened from the `Input` folder. A directory that is named by the date and time of image acquisition is created to store the images.

Chapter 4 Image Acquisition and Evaluation of Test 3: MLC Leaf Speed Test

Leaf Speed Test Procedure

Note: *The steps in the following procedure use the MV imager to acquire test images. The same evaluation can be done with different measurement devices (such as film).*

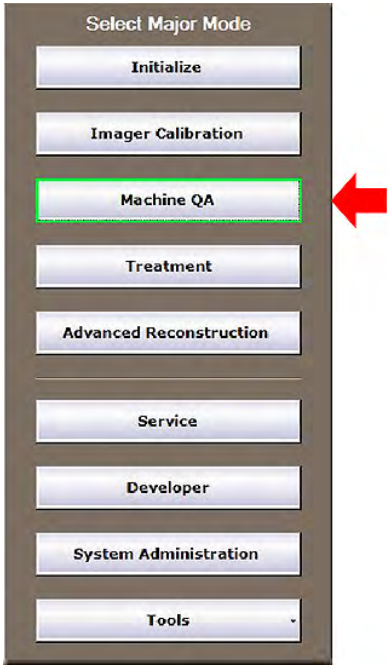
Note: *The MV imager needs to be calibrated for the Dosimetry Imaging Technique for the energy mode and the dose rate used in the RapidArc QA plans, i.e. 6x, 600MU/min.*

Note: *The MV imager should be positioned so that the lateral and longitudinal positions are equal to 0. Images acquired in the following procedure were acquired at 100 cm source-to-image plane distance.*

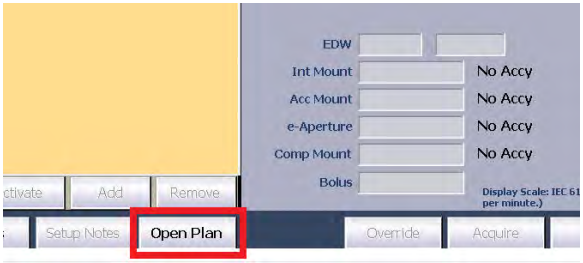
1. Extract the RapidArc QA files to a location that is accessible from the treatment console.

Note: *Typically, the I: drive is used to store files that will be accessible from the TrueBeam Treatment console.*

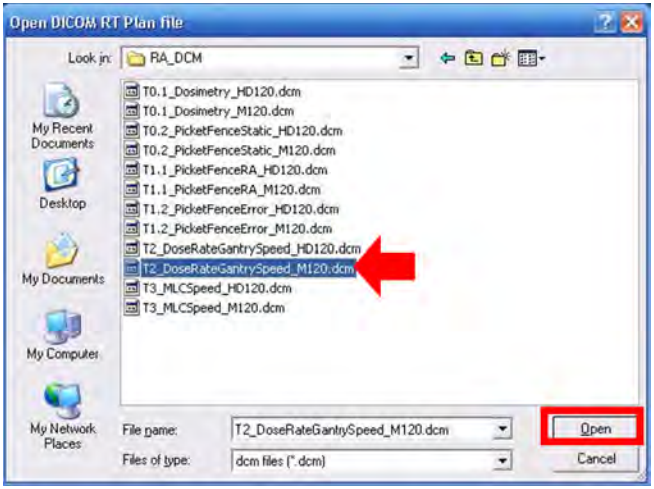
2. From the TrueBeam workstation, log into Machine QA mode.



3. Select **Open Plan** to open the DICOM RT file with the test plan.



4. Navigate to the folder with DICOM RT files.
5. Select the file with the test for the MLC model used, and click **Open**.

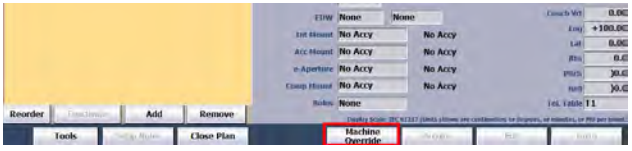


Note: *The test files do not contain Second Channel Integrity Check (SCIC) data. The treatment application may issue a warning to confirm changes before using the plan. If a warning is issued, enter your login credentials and click Continue.*

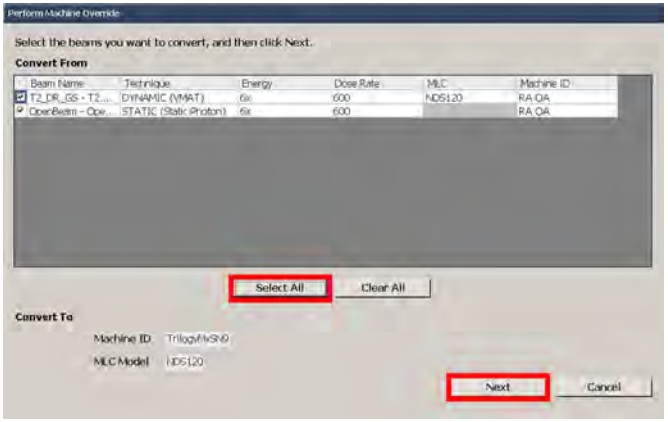
The imaging application may warn you that the loading of RT Structure set and/or RT images failed. This is because test plans do not contain images or structure sets, but may reference them.

If the installation has Advanced Imaging Auto Beamhold, the Motion Management Devices window appears so that you can select a device for the procedure.

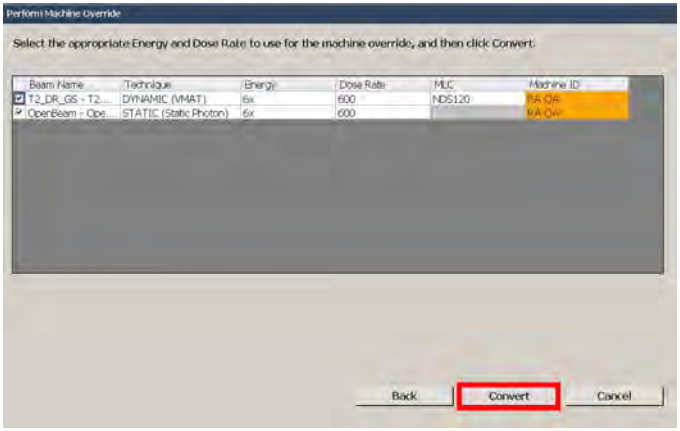
6. Read and acknowledge each warning message by selecting it, and then click **OK** to continue.
7. Click **Machine Override**.



8. Enter your username and password to authorize the override, and click **OK**.
9. Click **Select All** to override all of the fields.



10. Confirm the energy of the fields and click **Convert**.

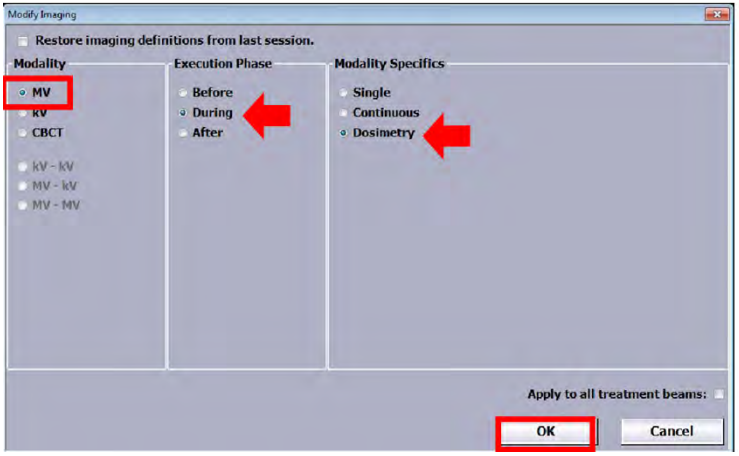


A summary window informs you whether the override was successful.

11. Click **Done** to close the summary window.
12. Highlight the first field in the plan and choose **Add** > **Add Imaging**.

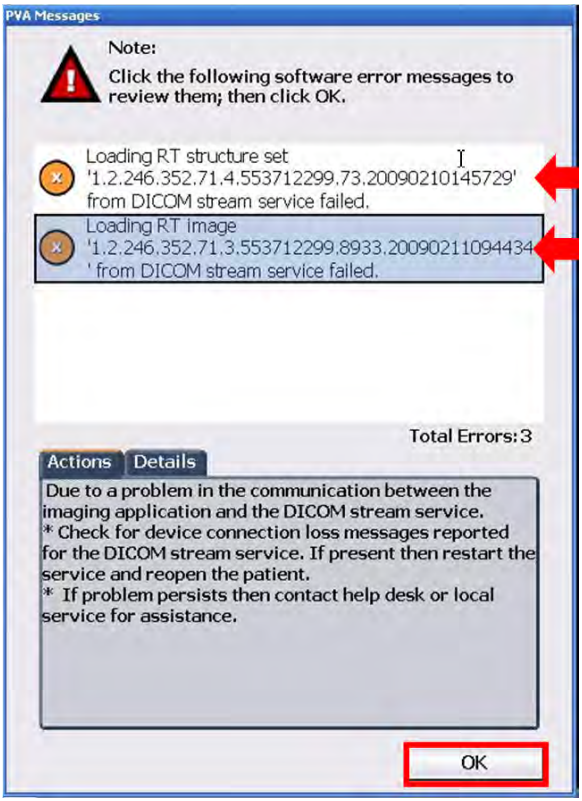
The Modify Imaging window appears.

13. Select the following options and then click **OK**:
    - Modality: MV
    - Execution Phase: During
    - Modality Specifics: Dosimetry

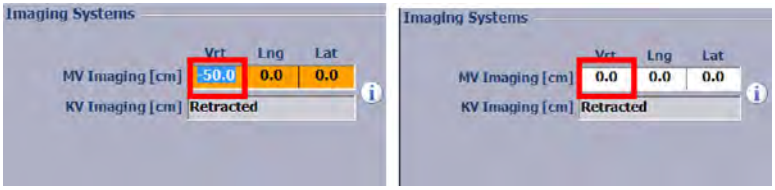


If the panel is still at position where the area outside of the active imager is irradiated, then the imaging application warns that the collimator setting will result in irradiation of the sensitive area of the imager.

14. Select the message and click **OK** to close the message dialog.



15. Set **Imager VRT** to 0 (the default position is −50), and then click **OK** at the bottom of the screen.



16. Repeat steps 12 to 15 to add imaging procedures to the second field.

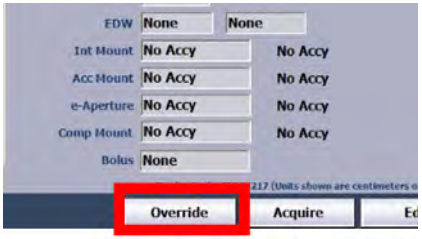
17. Highlight the first field.

18. At the control console, click **Prepare**.

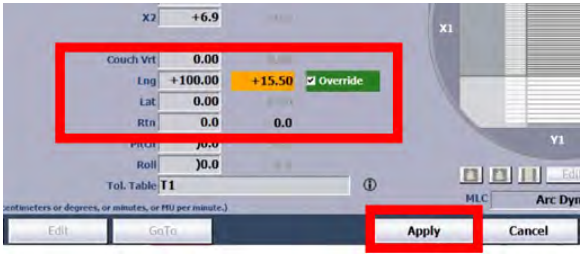
    A clearance caution message appears.
19. Click **OK** to clear the message and continue.
20. Ensure that the couch is retracted.
21. Move the gantry and imager axes to position.

    To avoid possible collisions, retract the couch and check to ensure clearance of the rotating gantry.
22. Override the couch positions, if required.

    a. Click **Override**.

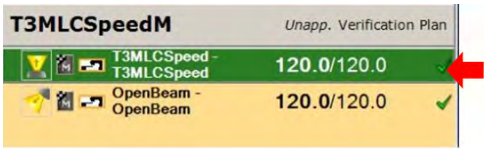


    b. Select the couch axes to override and click **Apply**.



    c. Enter your user credentials to authorize the Override.
23. When all of the interlocks clear, press **MV Ready**, and then **MV Beam On** to deliver the beam.

24. Repeat steps 18 to 23 to deliver the beam and acquire images for the remaining fields in the plan.
25. Highlight the first field.

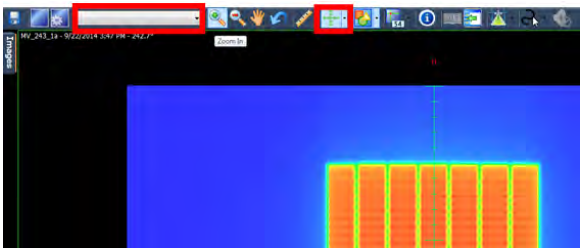


The acquired image displays in the Imaging Application.

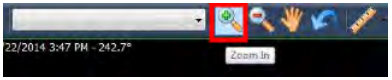
26. In the toolbar, click **Show/Hide Reference Image**  to hide the reference image.

    Alternatively, you can hide the image by maximizing the view with the acquired image.

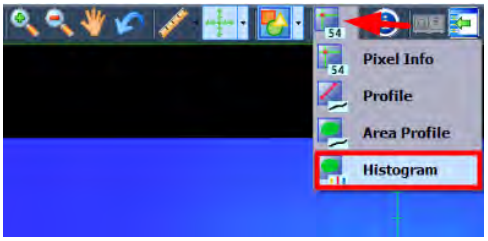
27. Make sure the Graticule is enabled and no filter is selected.



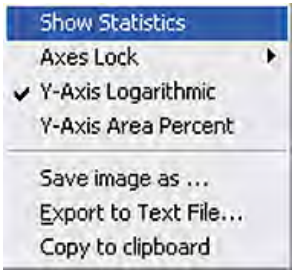
28. Select the **Zoom In** tool and zoom in on the image.



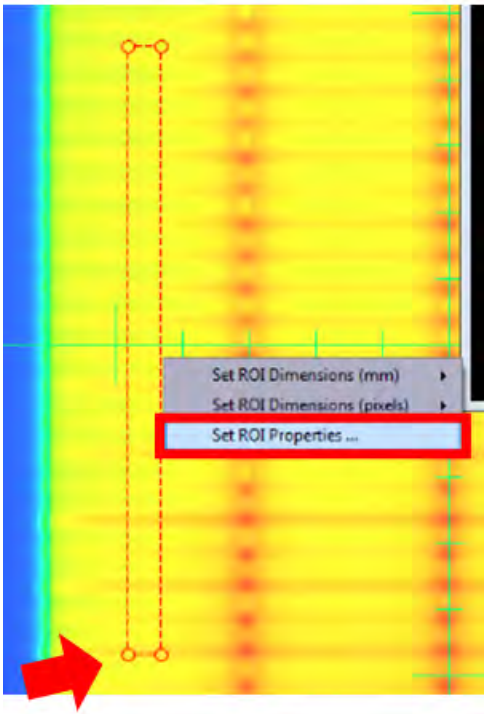
29. Select the **Area Histogram** tool to enable the Area Histogram.



30. Draw a region of interest (ROI) on the image.
    The Histogram window appears.
31. Right-click the histogram and select **Show Statistics** from the context menu.

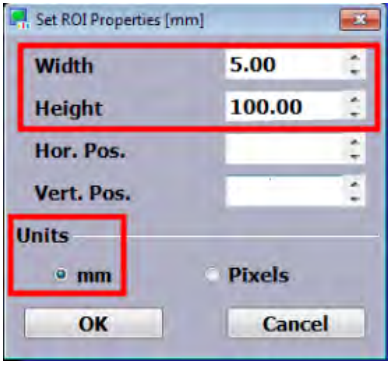


32. Right-click a corner of the ROI border and select **Set ROI Properties** from the context menu.



The ROI Properties dialog box appears.

33. Set the following properties:
    - Unit: mm
    - Width: 5 mm
    - Height: 100 mm

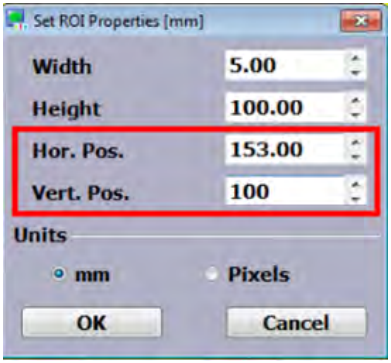


34. Center the ROI within the first vertical band by setting the horizontal and vertical positions Band 1 (see table) and clicking **OK**.

    The ROI should be centered on the graticule horizontal axis, and centered within the band on the graticule vertical axis.

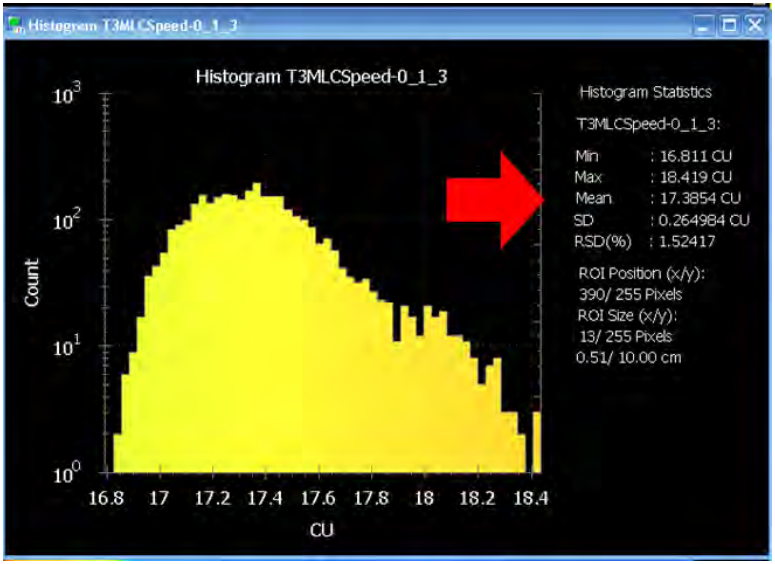
Band	Center of Band	ROI Hor. Pos.	ROI Vert. Pos. aS1000 Imager Configuration	ROI Vert. Pos. aS1200 Imager Configuration
1	−4.5 cm	153.0 mm	100 mm	150 mm
2	−1.5 cm	183.0mm		
3	+1.5 cm	213.0 mm		
4	+4.5 cm	243.0 mm		

The image below shows ROI properties for an aS1000 imager configuration. For an aS1200 configuration, Vert. Pos. should be 150 mm.

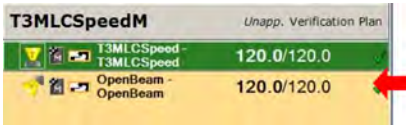


35. Write down the mean pixel value indicated by the histogram statistics.

    You will need the value for calculations in a later step.



36. Repeat steps 34 to 35 for Bands 2 through 4 (see table in step 34).
37. Select the open beam.



The acquired image displays on the Imaging screen.

38. Repeat steps 29 through 36 to record open field pixel values at the same ROIs as the test image.
39. Calculate corrected reading at all ROIs using following formula:

$$R_{corr}(x) = \frac{R_{LS}(x)}{R_{Open}(x)} \cdot 100$$

Where:

- $R_{corr}(x)$ is the corrected reading at a given ROI
- $R_{LS}(x)$ is a test image reading
- $R_{Open}(x)$ is an open field reading

40. Calculate the deviation of each ROI from the average value for all the ROIs.

$$diff(x) = \frac{R_{corr}(x)}{\bar{R}_{corr}} \cdot 100 - 100$$

Where:

$\bar{R}_{corr}$ is the average of $R_{corr}(x)$ for all four strips.

Machines using these plans will typically achieve numbers below 3% for each $diff(x)$.

41. Calculate the average of the absolute value of all $diff(x)$ values:

$$Diff_{abs} = \overline{|diff(x)|}$$

Machines using these plans will typically achieve numbers below 1.5% for $Diff_{abs}$.

Note: *The typical values presented here are not Varian specifications. Typical results are provided as a guideline for the tests, but the users must determine the Clinical tolerances appropriate for their equipment.*

42. In the Treatment application, click **Close Plan**.

Images are saved in either the source folder, or in the `\\MyServer\VA_TRANSFER\TDS\MachineID\Treatment\` folder if the plans were opened from the `Input` folder. A directory that is named by the date and time of image acquisition is created to store the images.