Commissioning and QA of SGRT on Ring Gantry and Sim-RT installation

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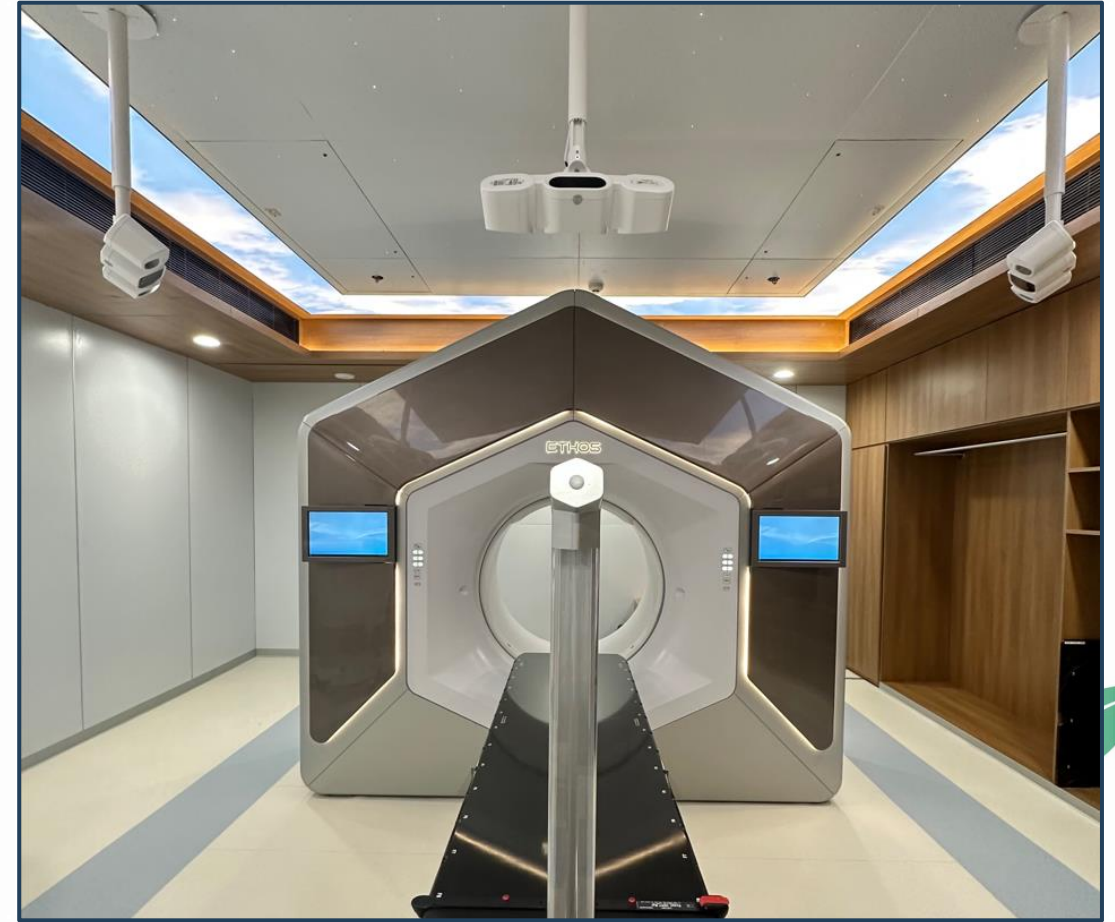
Mumbai

ETHOS : AI Driven Adaptive Radiotherapy

Delivery :

- 6X FFF Photon, Dose rate : 800MU/min
- Delivery at 2RPM
- Novel MLC :
  - ➢ Double Bank
  - ➢ Stacked/Staggered
- Beam Stopper

Imaging:

- kVCBCT
- Imaging at 4rpm: ~ 17seconds acquisition for kV CBCT
- Large FOV up to 49cm Ø X 24.5cm Length
- Extended CBCT range (38.5 cm)
- Iterative CBCT available for all protocols
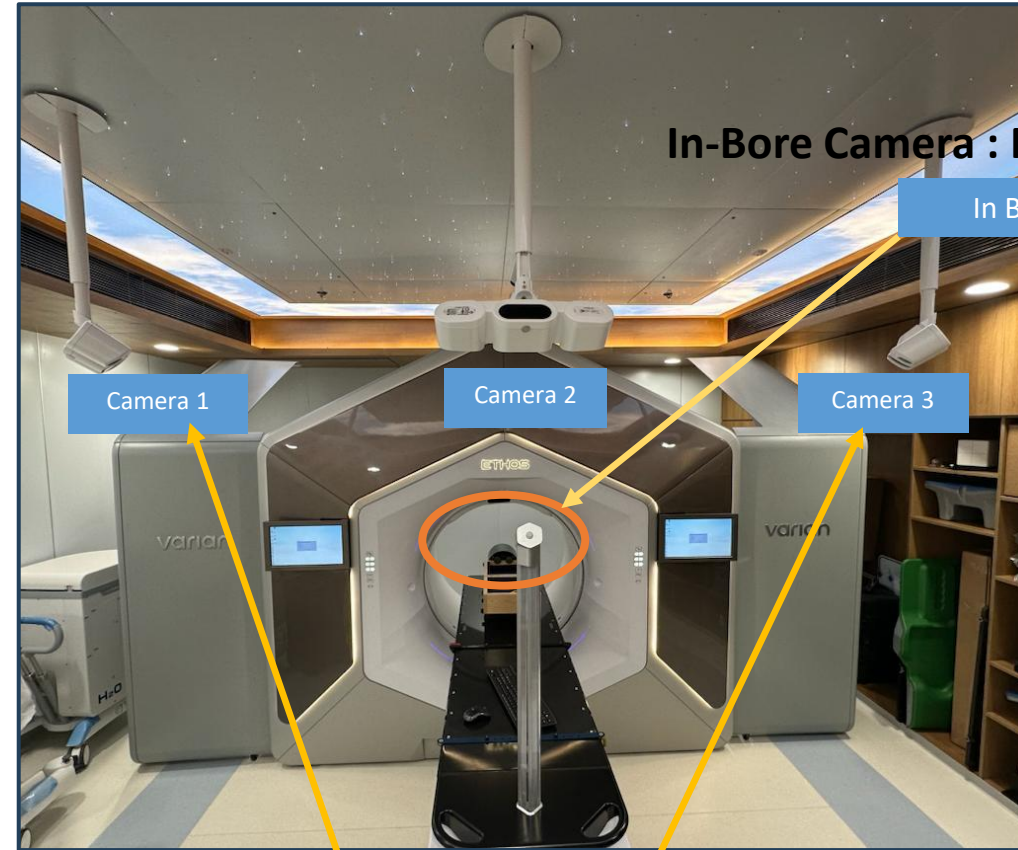
ETHOS : AI Driven Adaptive Radiotherapy

Not available :

- Optical Light Field
- ODI
- Hand Pendent
- Couch rotation
- Jaws
- Electron beams
- No MV imaging

C Type Linac Vs Ring Gantry Linac : SGRT

**C Type Linac : Only Celling Mounted Camera**

In-Bore Camera : Patient Monitoring

In Bore Ring

Camera 1

Camera 2

Camera 3

Camera 1

Camera 2

Camera 3

Celling Mounted Camera : Patient Setup

ALIGNRT setup

- **Setup**
  - Three ceiling mounted camera pods
  - One central and two lateral pods

- **Surface Reconstruction:**
  - Each pod contains two camera sensors and a projector enabling real time 3D surface reconstruction

- **Registration**
  - The live surface is registered to a reference surface generating 6DOF shift information (real time deltas)
  - Frame rates up to 25 fps with AlignRT v6.0

Each pod contains a projector, two image sensors (cameras) and a white Calibration LED

Image sensor — Image sensor

Status LED — White Calibration LED — Projector
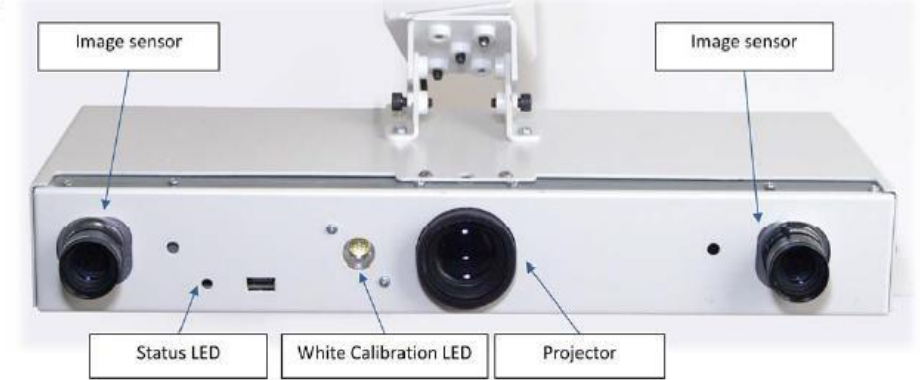
Projector - Projects a pseudo-random speckle pattern onto the patient surface which provides texture variations required for the reconstruction process

Image sensors – Acquire the raw textured data used for 3D surface reconstruction

White Calibration LED – Used for illumination during system calibration
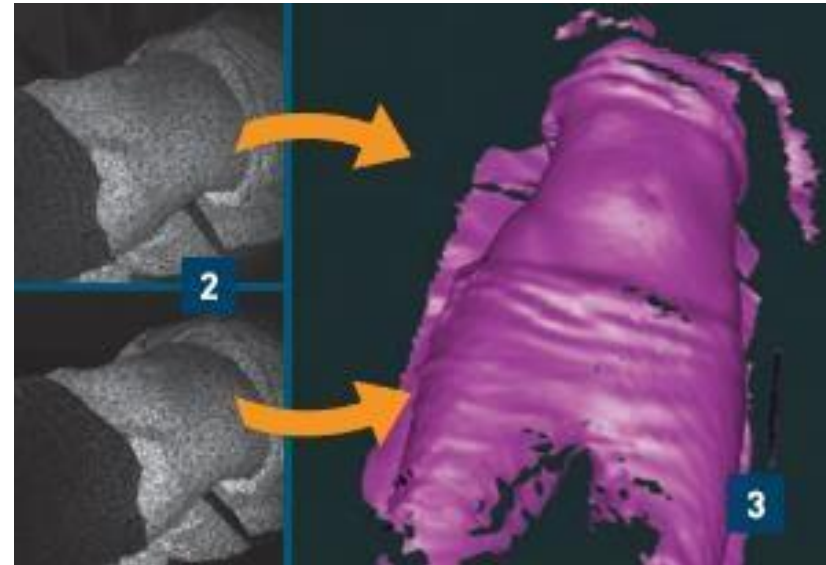
ALIGNRT – HOW IT WORKS

3 pods project a speckled red light pattern onto patient's surface

Stereo camera pods image pattern in 3D and software reconstructs full surface

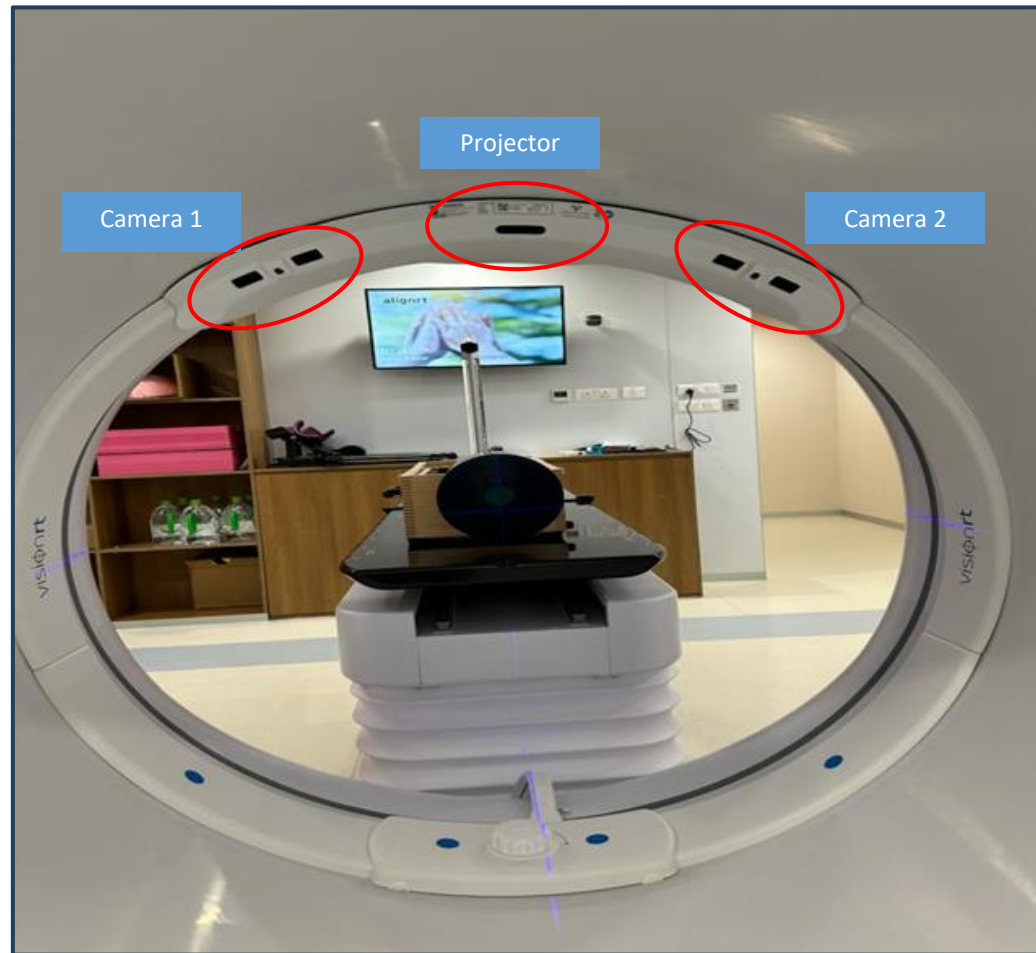Surface matched in real time to reference image (from CT or AlignRT)

In Bore Camera

In Bore Camera : Patient Monitoring

In Bore Camera Specification

- Three arch/Parts : Simple Locking clip system
- Dimension : 1m Diameter,
  Width : 16cm,
  Thickness : 3.0cm,
  Weight: 2.7kg

- Material : Carbon Fiber

- Rubber Fiction mounts around the ring

- Installed at Midway : Virtual Iso and Treatment ISO

SGRT in C Type Linac vs In Bore

No Visible Speckle pattern on surface
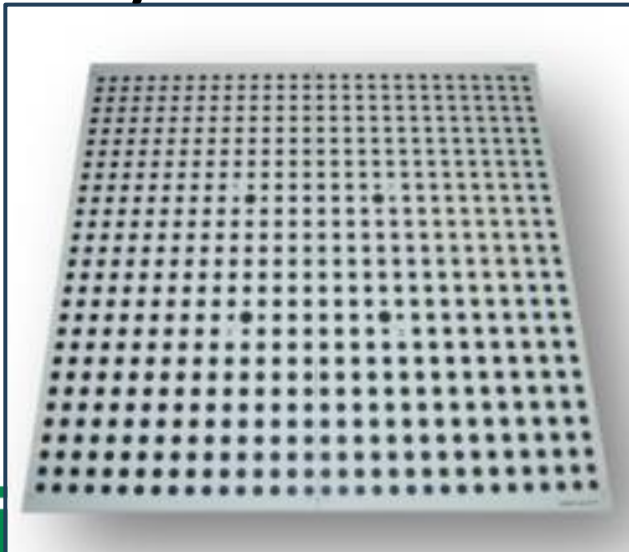
Speckle pattern on surface
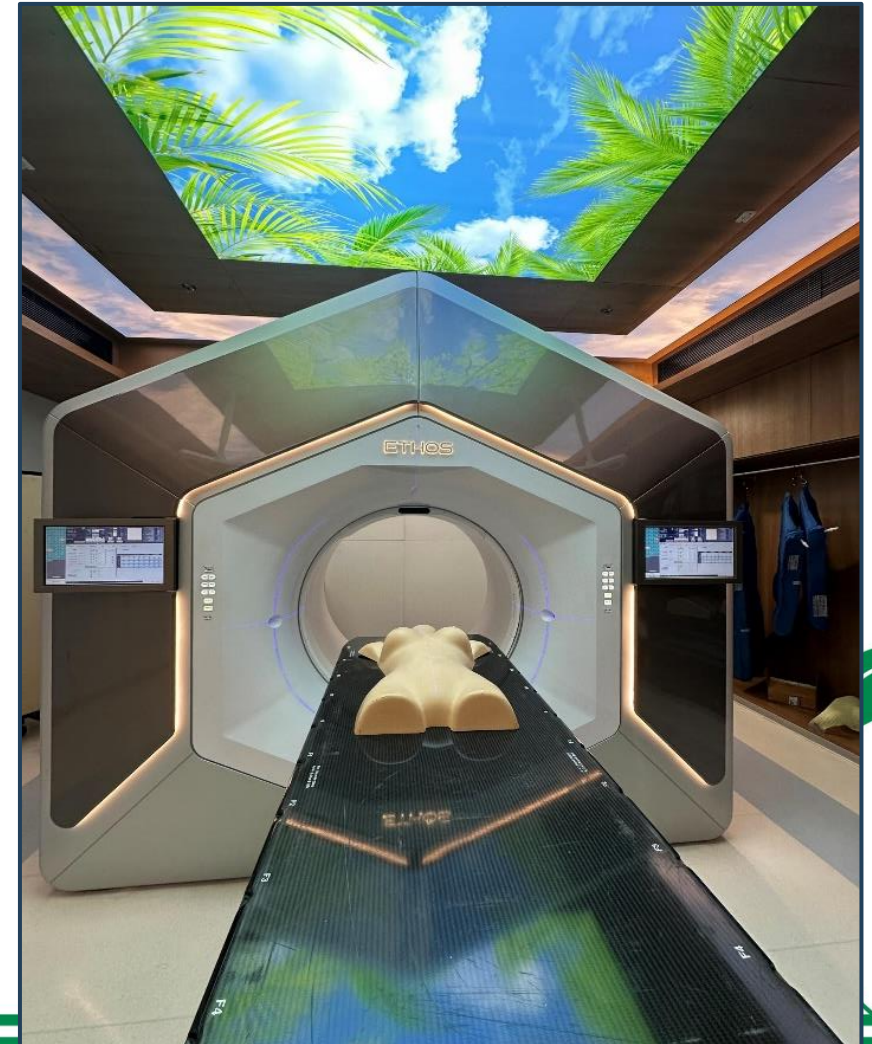
Phantom Used: Commissioning

MV Isocenter Cube Phantom

Mannequin

Daily Calibration Plate

Leg Phantom

Test Performed

- Plate Calibration

- Stability Of Camera In Bore and Celling Mounted

- Relative Shift accuracy

- Delta Stability and Pod Occlusion test

- Mechanical stability of In Bore Camera

Test Performed

- CBCT QA with and without Ring

- Dose measurement with and without Ring

- Integration test with ETHOS TPS

- Ambient Lighting : Alignment and Treatment

Stability of Camera

A phantom is monitored for 20 minutes

Test Name	In Bore Camera			Set up Camera		
	Maximum/Threshold	Error Read	PASS/FAIL	Maximum/Threshold	Error Read	PASS/FAIL
Thermal Stability	Drift LNG < 1.0 mm	0.20 mm	PASS	Drift LNG < 1.0 mm	0.37 mm	PASS
	Drift LAT < 1.0 mm	0.13 mm	PASS	Drift LAT < 1.0 mm	0.52 mm	PASS
	Drift VRT < 1.0 mm	0.11 mm	PASS	Drift VRT < 1.0 mm	0.29 mm	PASS
	Drift ROLL < 1.0 °	0.06 °	PASS	Drift ROLL < 1.0 °	0.08 °	PASS
	Drift PITCH < 1.0 °	0.08 °	PASS	Drift PITCH < 1.0 °	0.09 °	PASS
	Drift YAW < 1.0 °	0.04 °	PASS	Drift YAW < 1.0 °	0.09 °	PASS

Relative Shift accuracy : Tolerance (0.5mm)

In Bore Camera			
Test Name	**Maximum/Threshold**	**Error Read**	**PASS/FAIL**
Relative Shift Accuracy Test VRT + 10 mm	VRT error < 1.0 mm	0.29 ± 0.01 mm	PASS
Relative Shift Accuracy Test LNG + 10 mm	LNG error < 1.0 mm	0.06 ± 0.04 mm	PASS
Relative Shift Accuracy Test LAT + 10 mm	LAT error < 1.0 mm	0.08 ± 0.02 mm	PASS

Relative Shift accuracy : Tolerance (0.5mm)

Set up Camera			
Test Name	**Maximum/Threshold**	**Error Read**	**PASS/FAIL**
Relative Shift Accuracy Test VRT + 10 mm	VRT error < 1.0 mm	0.05 ± 0.03 mm	PASS
Relative Shift Accuracy Test LNG + 10 mm	LNG error < 1.0 mm	0.13 ± 0.03 mm	PASS
Relative Shift Accuracy Test LAT + 10 mm	LAT error < 1.0 mm	0.06 ± 0.05 mm	PASS

Verify Co- Calibration of SE up and In Bore Ring Camera : Tolerance (0.5mm)

SETUP Camera	Vert : 0.1mm
Real Time Monitoring 30Sec	Lng :0.1mm
	Lat : 0.1mm
In-Bore Camera	Vert: 0.1mm
Real Time Monitoring 30Sec	Lng: 0.3mm
	Lat: 0.3mm
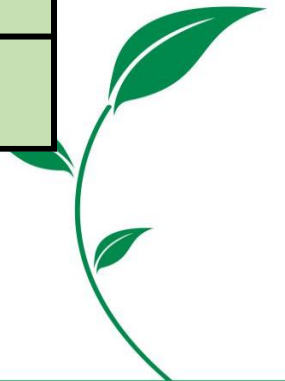
Delta Stability and Pod Occlusion test

Camera	Test Name	Maximum/Threshold	Error Read	PASS/FAIL
In Bore Camera	Delta Stability and Pod Occlusion Test Gantry at 0	LNG < 1.0 mm	0.14 ± 0.09 mm	PASS
		LAT < 1.0 mm	0.01 ± 0.03 mm	PASS
		VRT < 1.0 mm	0.10 ± 0.02 mm	PASS
		ROLL < 1.0 °	0.11 ± 0.01 °	PASS
		PITCH < 1.0 °	0.00 ± 0.03 °	PASS
		YAW < 1.0 °	0.05 ± 0.02 °	PASS
		MAG Std Dev < 0.2 mm	0.07 mm	PASS

Camera	Test Name	Maximum/Threshold	Error Read	PASS/FAIL
Set up Camera	Delta Stability and Pod Occlusion Test Gantry at 0	LNG < 1.0 mm	0.12 ± 0.03 mm	PASS
		LAT < 1.0 mm	0.47 ± 0.04 mm	PASS
		VRT < 1.0 mm	0.01 ± 0.03 mm	PASS
		ROLL < 1.0 °	0.02 ± 0.01 °	PASS
		PITCH < 1.0 °	0.01 ± 0.02 °	PASS
		YAW < 1.0 °	0.13 ± 0.01 °	PASS
		MAG Std Dev < 0.2 mm	0.04 mm	PASS

Ambient Lighting : Alignment and Treatment

Camera	Test Name	Maximum/Threshold	Error Read	PASS/FAIL
In Bore Camera	Ambient Lighting during Patient Alignment and Treatment	Drift LNG < 0.2 mm	0.02 mm	PASS
		Drift LAT < 0.2 mm	0.01 mm	PASS
		Drift VRT < 0.2 mm	0.01 mm	PASS
		Drift ROLL < 0.2 °	0.00 °	PASS
		Drift PITCH < 0.2 °	0.01 °	PASS
		Drift YAW < 0.2 °	0.00 °	PASS

Camera	Test Name	Maximum/Threshold	Error Read	PASS/FAIL
Set up Camera	Ambient Lighting during Patient Alignment and Treatment	Drift LNG < 0.2 mm	0.01 mm	PASS
		Drift LAT < 0.2 mm	0.00 mm	PASS
		Drift VRT < 0.2 mm	0.01 mm	PASS
		Drift ROLL < 0.2 °	0.00 °	PASS
		Drift PITCH < 0.2 °	0.00 °	PASS
		Drift YAW < 0.2 °	0.00 °	PASS

Accuracy and Reproducibility

- **Accuracy**

ΔVrt(cm)	ΔLong(cm)	ΔLat(cm)
0.01	0.02	0.01

- **Reproducibility was 0.02mm**

Our Initial QA Result of Adaptive with SGRT Ring

Sir H. N.
Reliance
Foundation Hospital
And Research Centre
RESPECT FOR LIFE

No Fraction	Gamma Pass%
Pre Treatment	
1	98.6
2	97.8
3	98.7
4	97.5
5	98.1
6	98
7	98.8
8	95.4
9	96.4
10	95.2
11	96.5
12	95.5
13	96
14	96.4
15	96.2
16	96.1
17	95.5
18	95.8
19	95
20	95.9
21	95.5
Avg	96.61

No Fraction	Gamma Pass%
Pre Treatment	
1	96.3
2	98.3
3	99.4
4	97.9
5	98.7
6	98.5
7	99.4
8	99
9	98.4
10	98.5
11	98.8
Avg	98.47

No Fraction	Gamma Pass%
Pre Treatment	
1	98.9
2	96.5
3	98.3
4	98.4
5	98.9
6	98.8
7	98.5
8	98.7
9	97.5
10	98.5
11	97.8
Avg	98.25

No Fraction	Gamma Pass%
Pre Treatment	
1	97.2
2	97.2
3	97.3
4	97.4
5	95
6	95.4
7	95.2
8	95.2
Avg	96.24

No Fraction	Gamma Pass%
Pre Treatment	
1	96.6
2	95.3
3	96.6
4	98.8
5	97.8
6	96.9
Avg	97.00

Initial Experience-CBCT and SGRT Shift

Breast		176 #
Δvrt(cm)	Δlong(cm)	Δlat(cm)
0.23	0.47	0.17
0.38	0.20	0.21
0.31	0.34	0.19
0.46	0.30	0.32
0.23	0.37	0.40
0.18	0.32	0.27
0.30	0.27	0.33
0.20	0.22	0.17
0.32	0.58	-0.02
0.12	0.00	0.11
-0.22	-0.48	0.27

Prostate		250 #
Δvrt(cm)	Δlong(cm)	Δlat(cm)
0.08	0.07	0.06
0.09	0.03	0.13
0.09	0.05	0.03
-0.16	-0.32	0.04
-0.24	-0.34	-0.45
0.52	-0.34	0.02
0.27	0.02	-0.04
0.12	0.06	0.15
-0.02	0.08	0.38
-0.01	0.20	0.28
0.12	0.08	0.11

Frequency of QA

TABLE 5 Summary of routine QA tests to be performed daily, monthly, annually as specified in Table II of AAPM's Task Group 147[1]

Frequency	Test category	Methods	Accuracy
Daily	Safety	Check interlocks and clear FOV for all mounted cameras	Pass
	Static localization	Daily QA phantom positioned at isocenter and can track movement to isocenter from offset	2 mm
Monthly (in addition to daily tests):	Safety	Machine interface: gating termination, couch motion communication	Functional
	Static localization	Localization test based on radiographic analysis (i.e., hidden target)	2 mm 1 mm for SRS/SBRT
	Dynamic localization	Motion table or manual couch motion of monthly phantom by known distances	2 mm or less as per manufacturer spec.
Annually (in addition to all monthly tests)	Safety	Test/reset buttons, backup power supply, and emergency-off switches	Pass
		System mounting brackets (all cameras are secure)	Pass
	Integrity	Check camera settings if accessible	Unchanged from previous
	Stability (drift/reproducibility)	Drift measurement (over at least 1 h)	<2 mm over 1 h
		Reproducibility of localization	<1 mm after stabilizing
	Static localization (extensive)	Complete end-to-end test (including data transfer check of localization accuracy, etc.)	<2 mm from isocenter <1 mm for SRS/SBRT
		Translation and rotation auto correct over a clinical range of motion	<2 mm from isocenter
	Dynamic (gating system)	Using a motion phantom/check of gating system radiation dosimetry accuracy.	< 2% (per TG-142)
	Data transfer	From all systems in use	Functional

Limitation

- MMI : Motion Management Interface not available, No auto Beam Hold

- No Direct Integration to ETHOS

- Re-calibration of Ring Post Servicing of ETHOS

Conclusion

- This Acceptance test of In Bore camera proved that overall performance is comparable to celling mounted camera.

- In Bore camera SGRT system sufficiently verified for clinical use.

Sim RT :Installation and Commissioning

Sim-RT

- What is Sim-RT?

- Where Sim-RT?

- Why Sim-RT?

Guideline for Surface Guided Radiotherapy

ESTRO -ACROP: Guideline on Surface-guided radiotherapy
AAPM Task Group-302:Surface-guided radiotherapy

Installation and Commissioning

- *"Installation and commissioning is part of the QA Program and it includes testing a system capabilities and verifying its accuracy/precision in all clinically relevant scenario."*

- Steps:

1.Installation Components.

2.Accepatrance/QA Test Performed.

Main Components Used in Installation of Sim-RT

Camera Mount

Camera hook and barrel nut
-- This is where the camera connects to the vertical mount

Inner mount

Outer mount

Triangle cage

T - piece
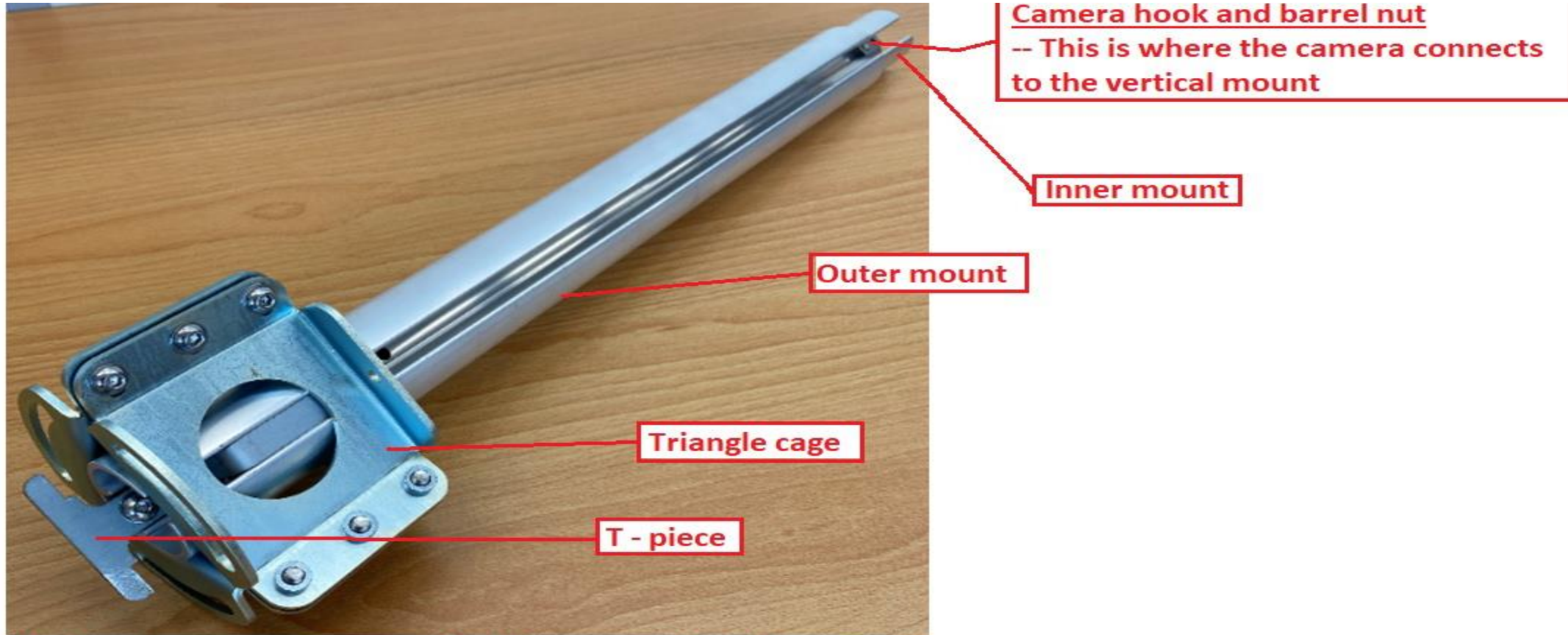
All these items are pre-assembled from manufacturing
--Outer and Inner mount set to length at manufacturing

Main Components Used in Installation of Sim-RT
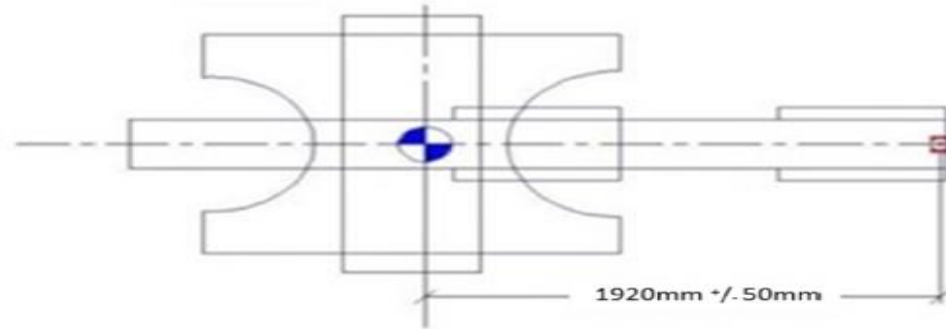
Celling Plate and Horizon Camera

Main Components Used in Installation of Sim-RT

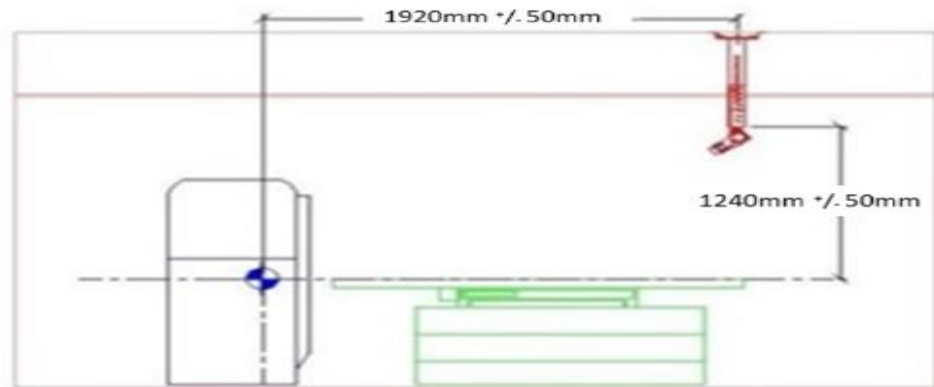- Real time coaching device and Calibration Plate
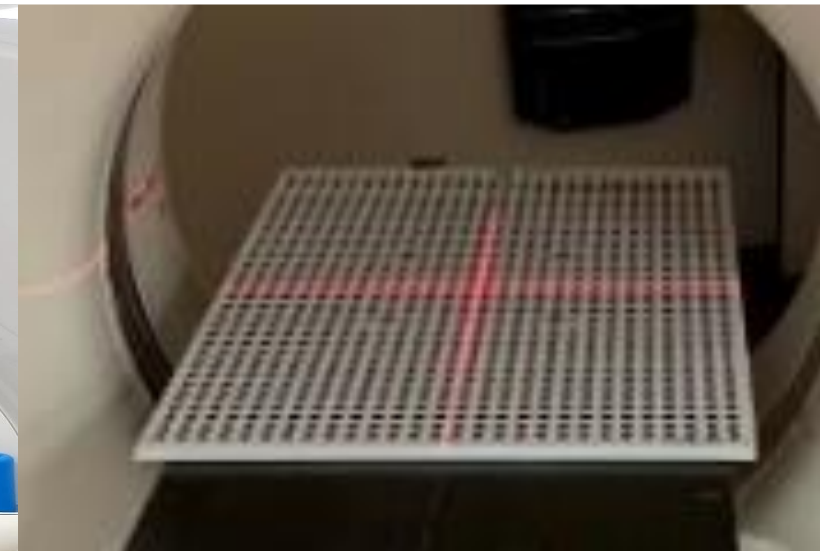
Camera Layout

CT Simulation Room Plan View

1920mm +/-50mm

CT Simulation Room Sectional View

1920mm +/-50mm

1240mm +/-50mm

Commissioning and QA Test

- The following tests are conducted and validated the Sim-RT system:

  - System Calibration(Monthly QA)

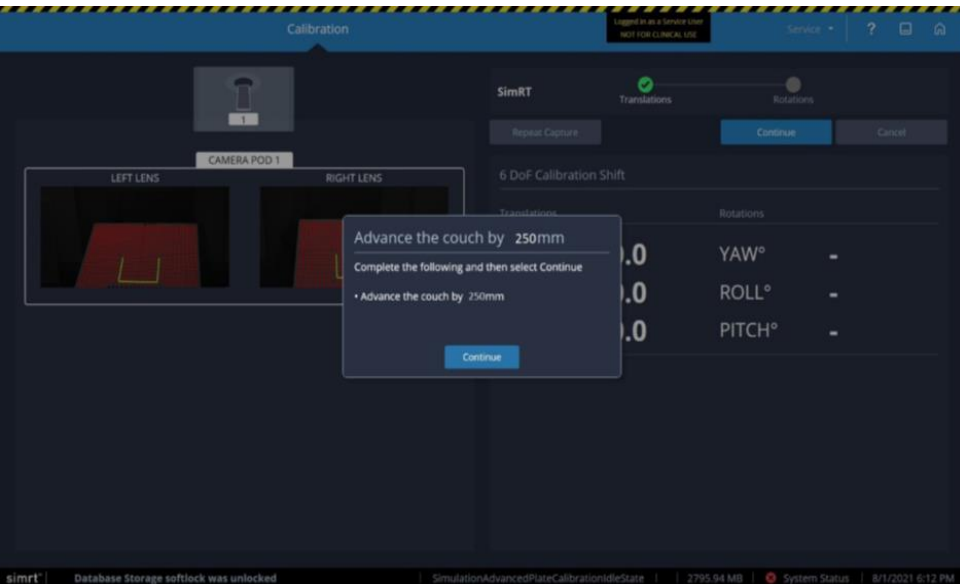 - Daily QA

- Validation Test

Monthly Calibration

- Step 1. Place the calibration plate on the couch at bore centre.

- Step 2. Open SimRT using your account.

- Step 3. Click on the System **Calibration Icon.**

- Step 4. Follow the instructions on the screen and click "Start Calibration" button.

- Step 5. Click the landmark points, 1-4 as shown in image
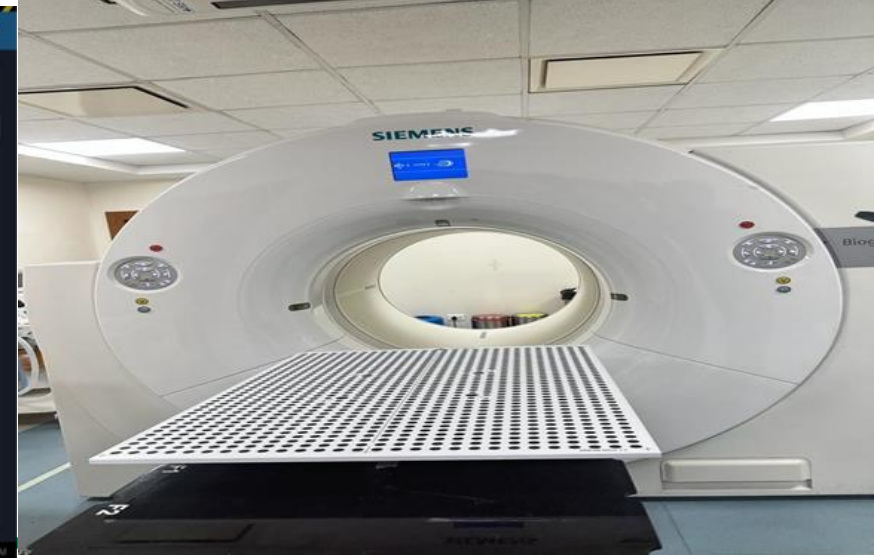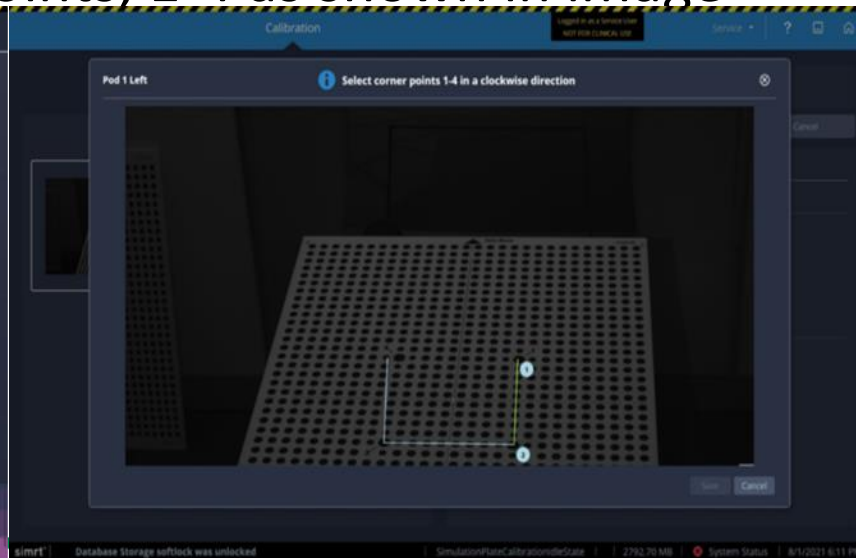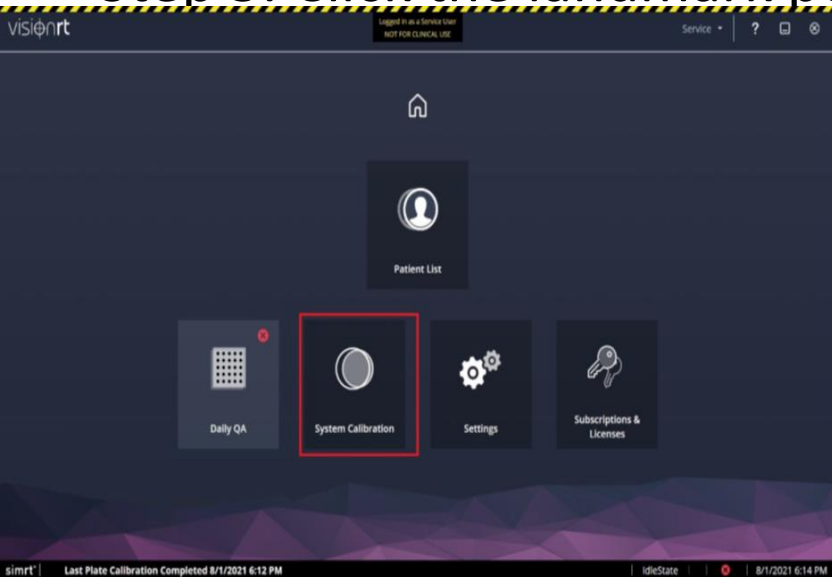
Monthly Calibration

- Step 6. Next click "Continue"

- Step 7. The software will ask to advance the couch by 25cm into the bore. Advance the CT couch and then click "Continue".

- Step 8. Select the landmark number corner points in order 1-4 as shown below.

- Step 9. Click **"Apply"** and then click "OK". Monthly Calibration is completed.

DAILY QA

- The Daily QA verifies there has been no camera pod movement since the last monthly calibration.

- *Note*: Daily QA must be performed after any Monthly Calibration for Sim-RT to function properly.

- Step 1. Place the calibration plate on the couch at bore centre.(Same As Monthly QA)

- Step 2. Open SimRT using your account.

- Step 3. Click on the System **Daily QA Icon.**

- Step 4. Click on "Start Daily QA"
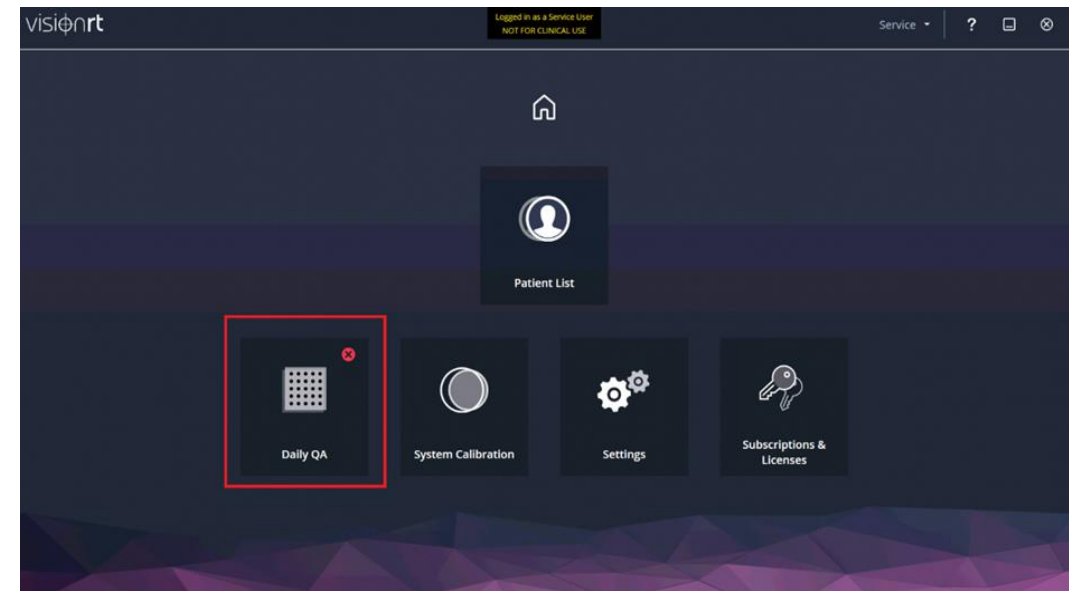
DAILY QA

- Step 5. The software will ask to advance the couch by 25cm into the bore. Advance the CT

- couch and then click "Continue". And Observe the shift
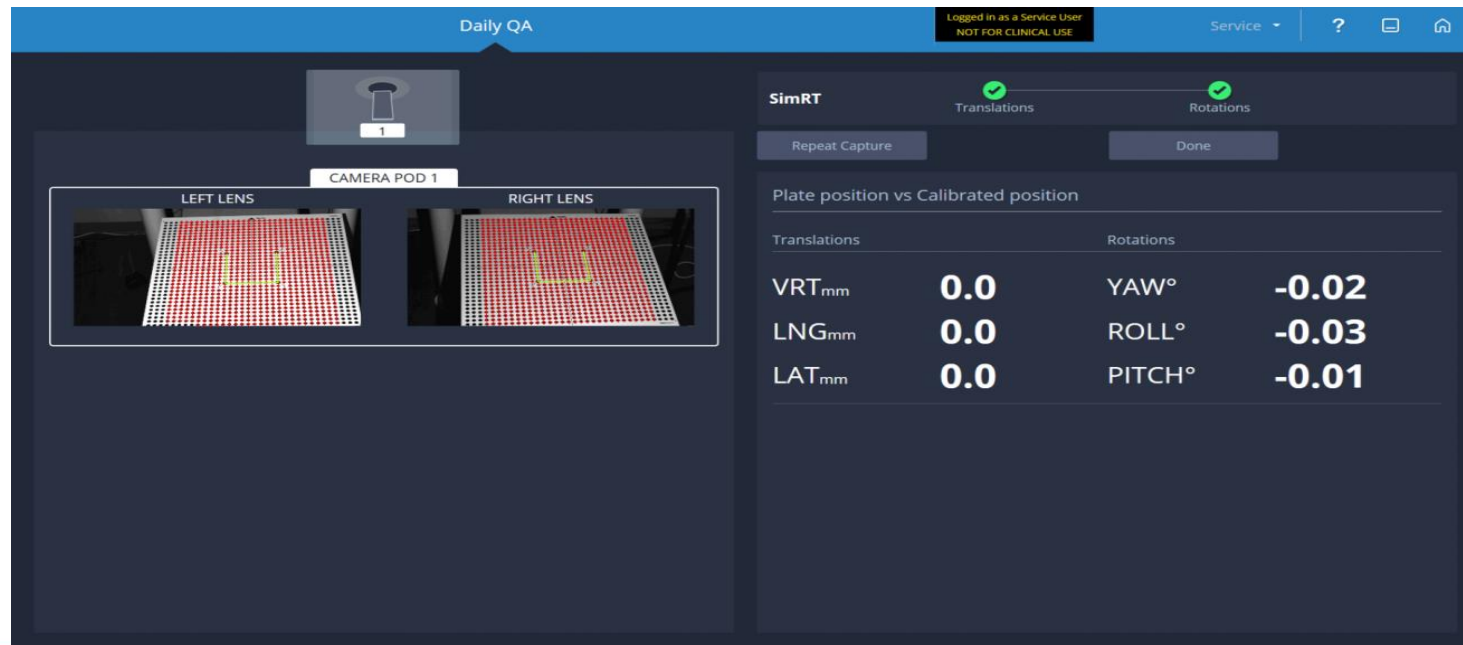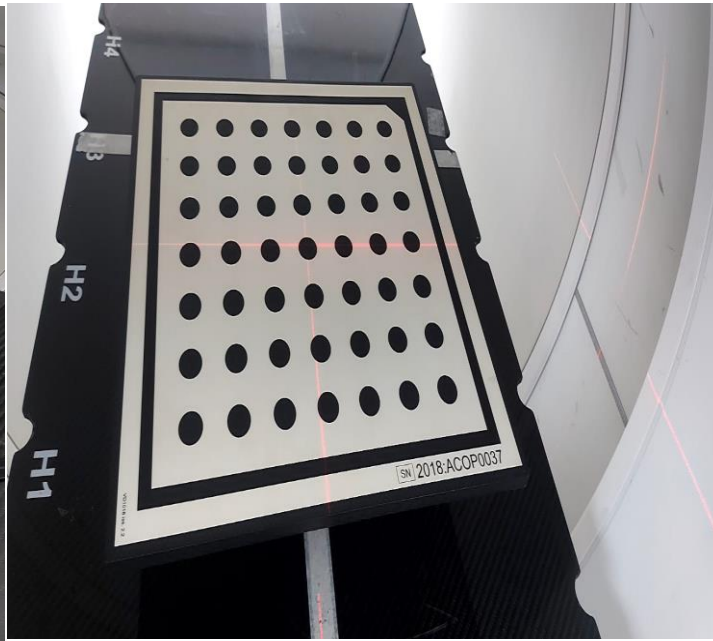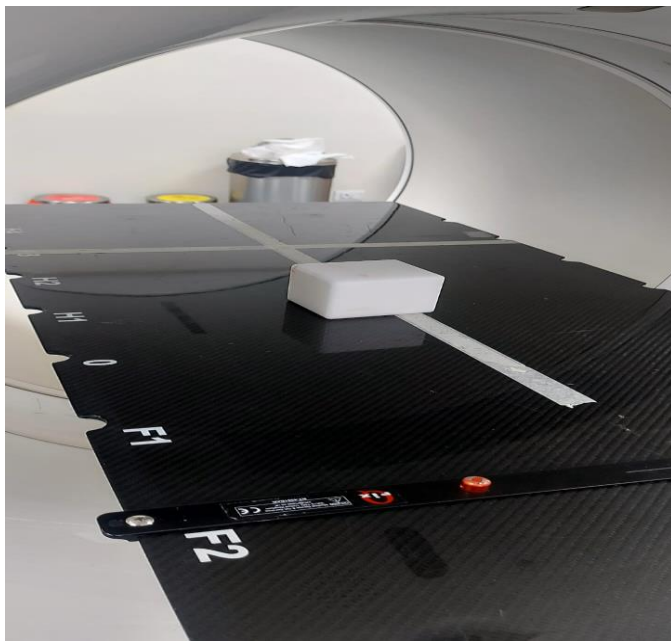
SIM RT Validation test

- Following test must be run in order to shown below.

1. **Shift Accuracy**: The Average displacement of each three shift computed from VXP files and compare to initial one and difference must be **< 0.5mm** .

2. **Monitoring Stability**: Standard deviation from VXP file **<0.2mm.**

3. **Frame Rate:** frame rate from VXP file **> 25fps.**

SIM RT Validation: Create a VXP file(5min)

Setup:

- Set a SimRT Spacer at its lowest height(7cm) and aligned with room laser,

- Place a ACO plate on the Spacer and aligned with room laser(see following picture.)

SIM RT Validation: Create a VXP file

- Create A test Patient(Patient Name Sim RT Validation)

- Choose a "DIBH(3D Helical) Protocol"

- Capture a Surface of ACO plate.

- Position patch on centre of plate and monitor for 20sec.

- Stop monitoring and revive and export the file .

- Repeat for 8cm and 9cm ,export file .

- Do analysis of file in "Accuracy Validation tool "

SIM RT Validation: Create a VXP file:Result

Accuracy Validation Test (SimRT only)

System validation analysis test (SimRT only)

◉ Pass	○ Fail	○ N/A

Shift Accuracy: The average displacement for each of the three shifts computed from VXP files and compared to the ground truth.

Pass

0mm shift error <0.5mm	0.06	- +
10mm shift error <0.5mm	0.20	- +
20mm shift error <0.5mm	0.07	- +

Monitoring Stability: Standard deviation of the displacement values computed from VXP file.

Pass

| Standard deviation <0.2mm | 0.04 | - + |

Frame rate: Frame Rate computed from VXP file

Pass

| Frame rate > 25fps | 35 |

Advantages

- Tracking Point Selection inside the CT Room

- The Ceiling Mounted Camera allows for no physical marker, block or belt needed
    - no physical distraction for patients

- no skin deformation, no inaccurate block placement, and nothing to clean.

- completely non-invasive and non-ionising motion monitoring.

- Real Time Coach Display for coaching and monitoring breathing pattern

- Advance Software for tracking and monitoring

- quick and efficient setup

- Doesn't require any additional equipment to be setup for each patient

Thank You