GETTING STARTED WITH SURFACE IMAGING:
SYSTEMS OVERVIEW, COMMISSIONING, AND ONGOING QA

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DISCLOSURES

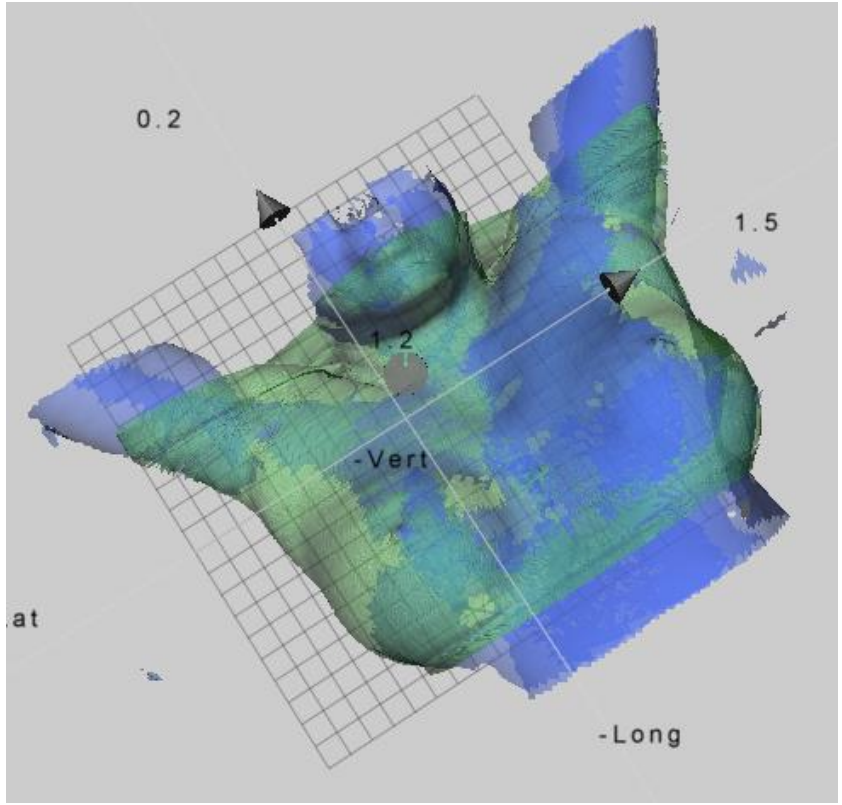
- I have nothing to disclose.
- System overview slides were provided by each vendor.

OVERVIEW

- Basics of the commercially available systems
  - C-RAD - Catalyst HD
  - Varian(HumediQ) – Identify
  - VisionRT - AlignRT/OSMS
- Initial implementation and commissioning
- Ongoing QA

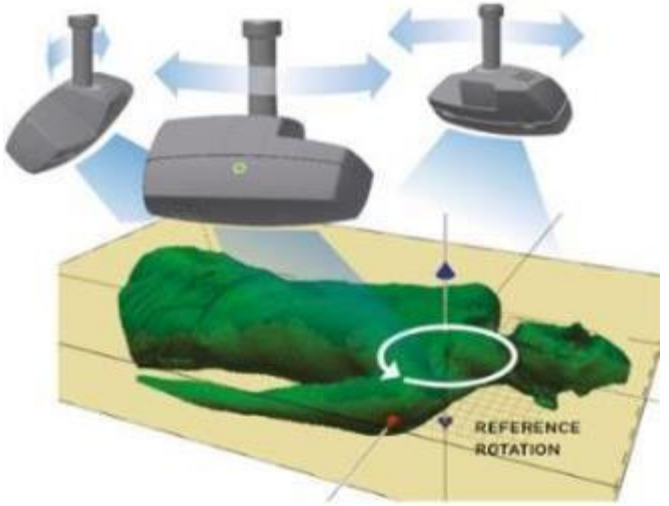
BENEFITS OF 3D SIGRT

- Goal: Improve the overall accuracy of radiation delivery
  - Patient positioning
    - Improve inter-fractional set-up accuracy
    - Monitor patient surface changes
  - Patient monitoring
    - Monitor patient intra-fractionally
    - Quantify inadvertent movements
  - Gated delivery
    - Efficient gating tool for motion management
    - Simultaneously monitor patient position, patient motion and respiratory breathing trace



CATALYST HD - OVERVIEW

- **Physical specifications**
  - Three cameras ~120°apart from one another
- **Light projection**
  - Wavelengths: 405 nm (near-invisible violet), 528 nm (green), 624 nm (red)
- **Hardware capabilities:**
  - Scan speed: 200 complete 3D surfaces / second
  - Scan volume (X*Y*Z) is 800mm*1300mm*700mm
  - Measurement accuracy: <0.5mm
- **Application performance:**
  - Long-term stability: 0.3 mm
  - Measurement reproducibility: 0.2 mm
  - Registration method: Real-time, non-rigid with deformable models for computing 6 DOF isocentric shifts
  - Positioning accuracy: Within 0.5 mm for rigid body
  - Motion detection accuracy: Within 0.5 mm



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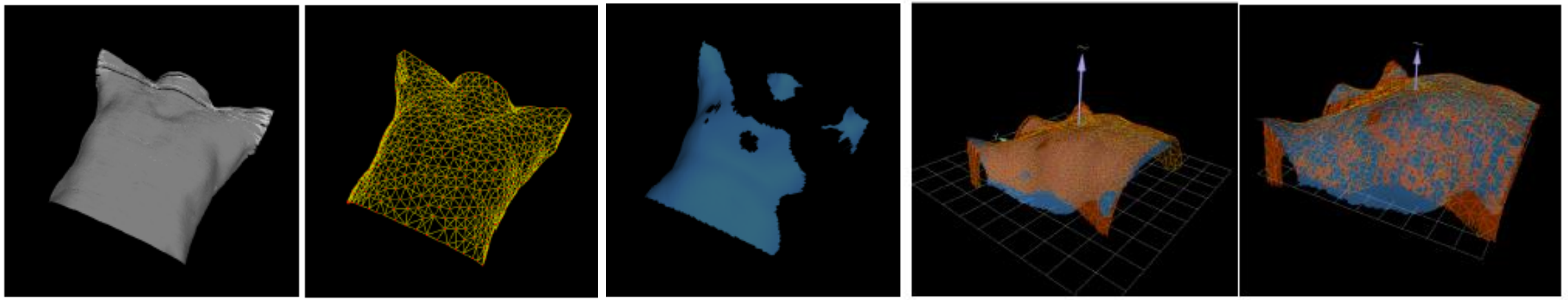
C-RAD CATALYST HD – HOW IT WORKS

Sequence of patterns are projected onto the patients surface

Camera measures the projected patterns and reconstruction compares projected and captured patterns to identify the coordinates of each pixel on the captured image



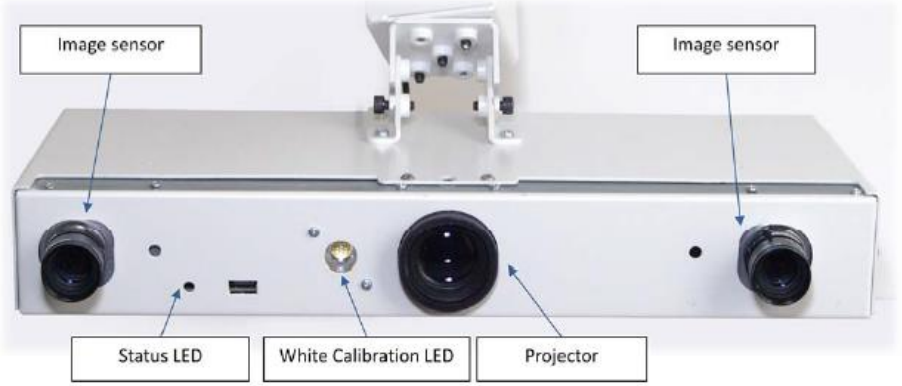
Source | Deformable node graph | Target | Initial alignment | Final registration

Zhang et al. 3DPVT (2002)

ALIGNRT

- **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



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

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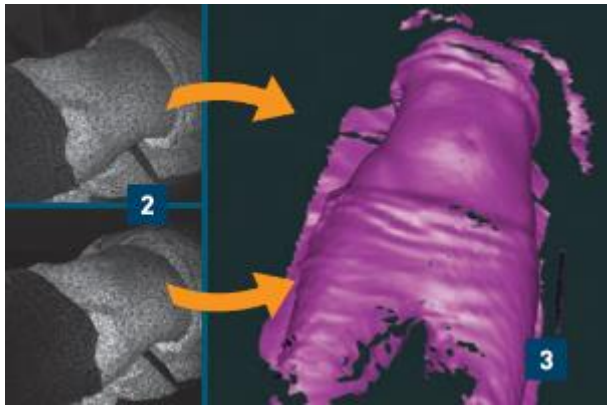
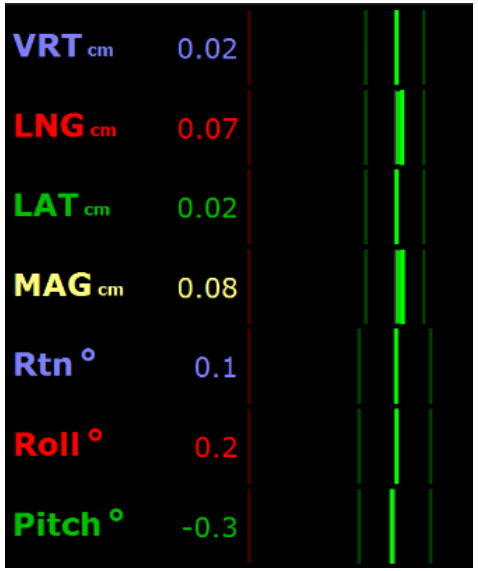
ALIGNRT – HOW IT WORKS

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)



IDENTIFY

- **Setup**
  - Four ceiling mounted camera pods
  - One central, two lateral pods and one time of flight
- **Surface Reconstruction:**
  - Each pod contains a projector and camera pair enabling rigid 3D surface reconstruction
  - Patient motion management with 3 SGRT camera system
- **Capabilities**
  - Biometric Patient Identification
  - Set up device ID and location verification, patient set up verification
  - Treatment session planning updates

THE BIG 3

System	Camera Hardware	Field-of-View (FoV)	Camera Resolution	Maximum Reported Frame Rate	Patient Positioning Corrections	Positioning Accuracy	Registration Algorithm
Align RT (Vision RT)	1 to 3 cameras (90° apart)	650 × 1000 × 350 mm^3	2048 × 1024 px (4MP)	50 fps	6D	<1.0 mm / 1.0°	Rigid
Catalyst HD (C-RAD)	1 to 3 cameras (120° apart)	1100 × 1400 × 2400 mm^3	640 × 480 px	200 fps	6D	<1.0 mm / 1.0°	Deformable
Identify (Varian)	2 to 4 cameras	800 × 800 × 800 mm^3	1280 × 1024 px (1.3 MP)	25 fps	6D	<1.0 mm / 1.0°	Rigid

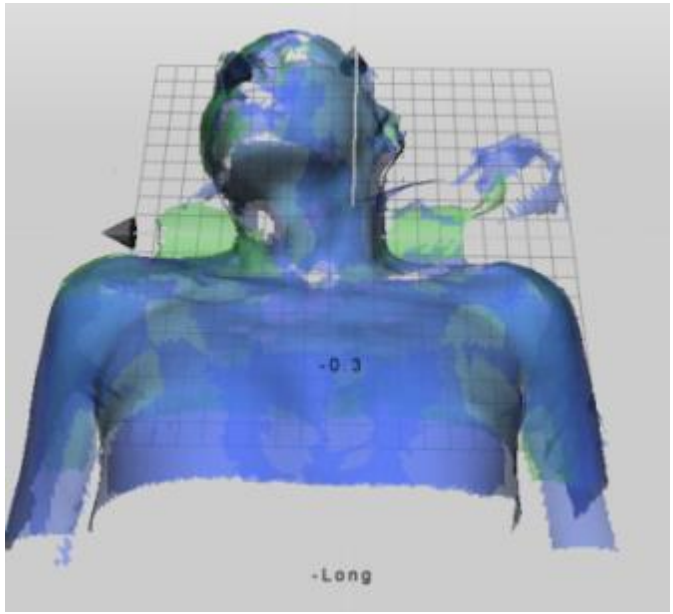
Gutierrez AN, Al-Hallaq HA, **Stanley DN**. "Surface Image-Guided Radiotherapy: Overview and Quality Assurance." Image Guidance in Radiation Therapy: Techniques, Accuracy, and Limitations, 2018 Summer School, edited by Parham Alaei and George Ding, vol. 39, AAPM, 2018, pp. 279–308

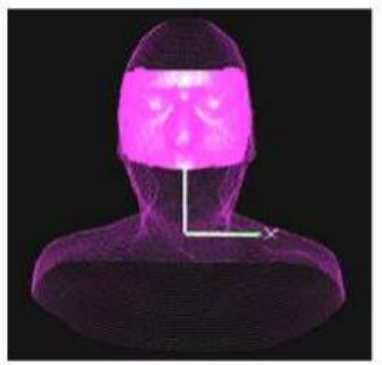
INITIAL COMMISSIONING AND IMPLEMENTATION

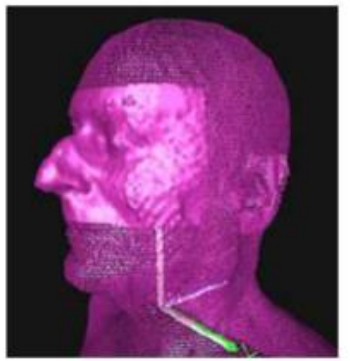
- Current standard is TG-147
- New recommendations coming from Task Group No. 302 - Surface Image Guided Radiotherapy
  - Not yet finished
  - Statement from TG-302 committee page
    - “1) Recommendations for DIBH & SRS have been agreed upon. QA recommendations are currently being revised. 2) Writing of each section has commenced by various members. 3) Writing of survey manuscript in progress. 4) Request renewal of TG-302 for 1 additional year in order to finalize the report.”

COMMISSIONING ACCORDING TO TG -147

1. Integration of Peripheral Equipment
   a) Communication with Record and Verify Systems
   b) Integration with the Linear Accelerator
   c) Determination of localization Field of View
2. Spatial Reproducibility and Drift
3. Static Localization Accuracy
   a) Localization Displacement Accuracy
   b) End-to-End Assessment
4. Dynamic Localization Accuracy
   a) Spatial Accuracy
   b) Temporal Accuracy
   c) Dynamic Radiation Delivery (gating/tracking)
5. Vendor-Recommended Assessment
6. Documentation
7. Standard Operating Procedures







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UAB MEDICINE

RADIATION ONCOLOGY

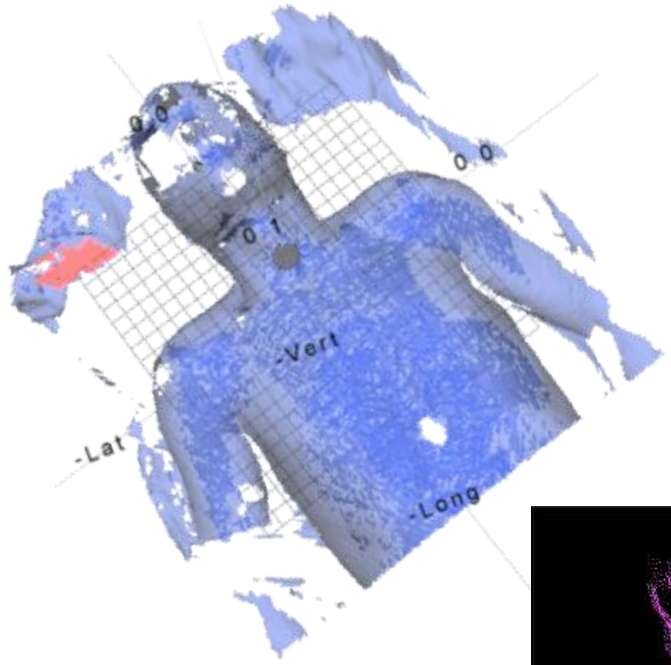
Willoughby T, Lehmann J, Bencomo JA, et al. Quality assurance for nonradiographic radiotherapy localization and positioning systems: report of Task Group 147. Med Phys. 2012;39(4):1728–47.

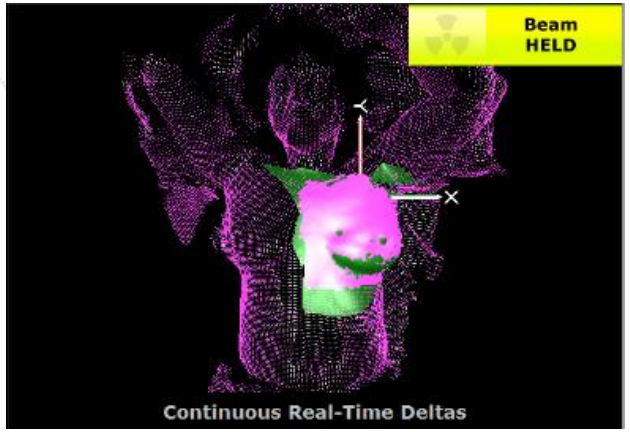
COMMISSIONING TESTS

1. Verify integration and safety interlocks
2. Verify field of view
3. Perform temporal drift assessment
4. Perform static localization assessment
5. Perform dynamic localization assessment
6. Establish QA/calibration procedures
7. Vendor Specific Assessments
   - Settings optimization
   - Phantom selection

INTEGRATION OF PERIPHERAL EQUIPMENT

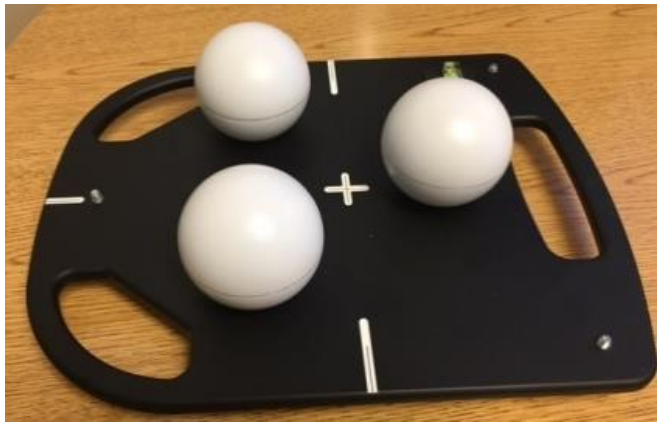
- Direct communication with R&V and Linac interface
- Validation of the following:
  - Correct patient selection with R&V
  - Correct coordinate system
  - Correct isocenter selection
  - Correct isocenter identification with multiple isocenters
  - Correct patient orientation
  - Correct units
  - Correct surface reconstruction
  - Interlock functionalities
  - Dynamic radiation delivery functionalities
  - Integration of automatic couch motion from console

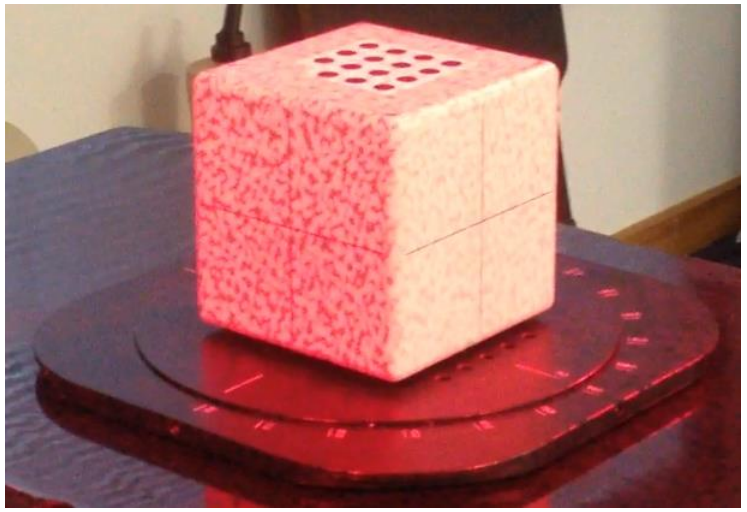




DETERMINATION OF LOCALIZATION FOV

- Equipment
  - Vendor specific QA device or commercially available multiple modality phantom
- Methodology
  - Visualization of phantom at isocenter
  - Measurement
    - Using couch offset phantom in all 6 directions
  - Record maximum clinical extent
    - Give yourself some buffer if you can!



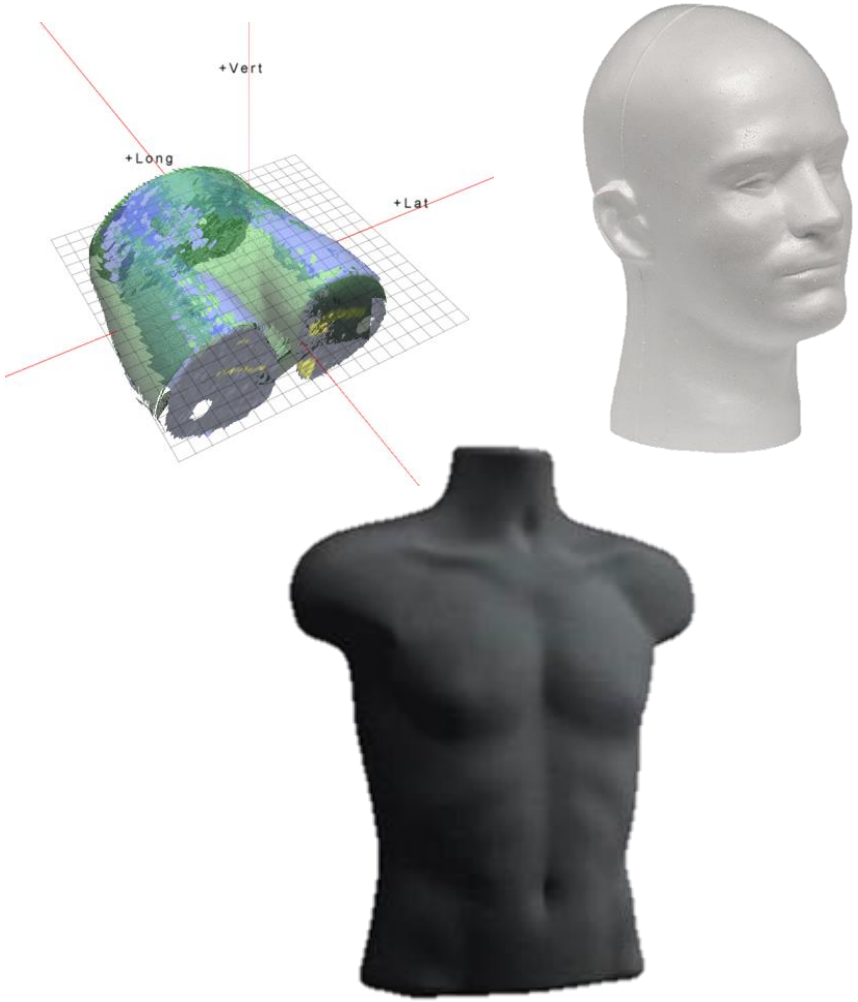


TEMPORAL DRIFT ASSESSMENT

- **Equipment**
  - Vendor specific QA device or compatible multiple modality phantom
- **Initial thermal equilibrium - Cold start method**
  - System initialized from a cold start
  - >24 hrs powered down
  - Immediately upon powering up the system perform imaging check
  - Repeat a periodic intervals without moving the phantom
  - Should be < 2mm in 1 hr
- **Artificial drift due to component heating**
  - Perform imaging check of stationary phantom
  - Repeated every 5 min without moving the phantom

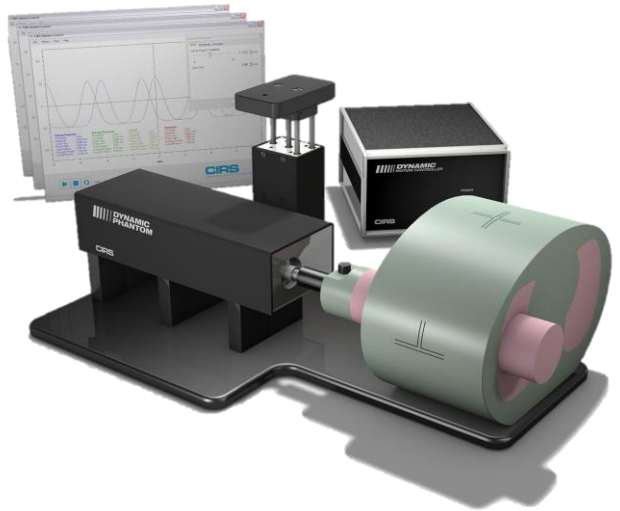
STATIC LOCALIZATION ASSESSMENT

- **Equipment**
  - Representative clinical anatomical phantom with implanted reference marker(s)
- **Methodology**
  - End-to-End static localization
    - Positional and rotational
  - Using couch control introduce displacements in lateral, longitudinal, and vertical direction.
    - Increments of <1 cm over clinical range
  - Differences recorded between SGRT system, couch positional indictors/“gold standard” imaging system
  - Recommended accuracy is within 2 mm over a 10 cm range in all directions for standard dose fractionations and within 1 mm over a 10 cm range for SBRT and SRS treatments



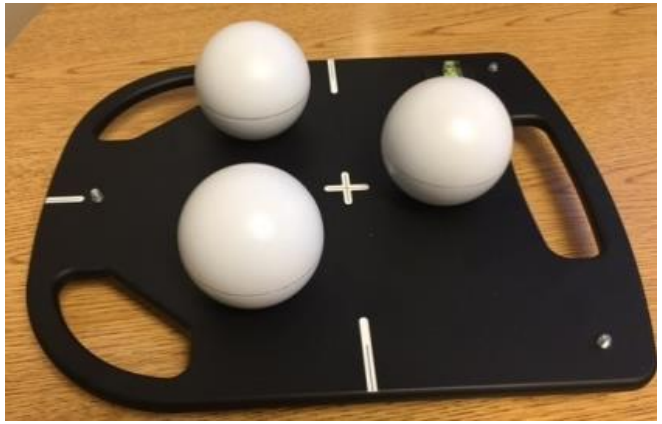
DYNAMIC LOCALIZATION ASSESSMENT

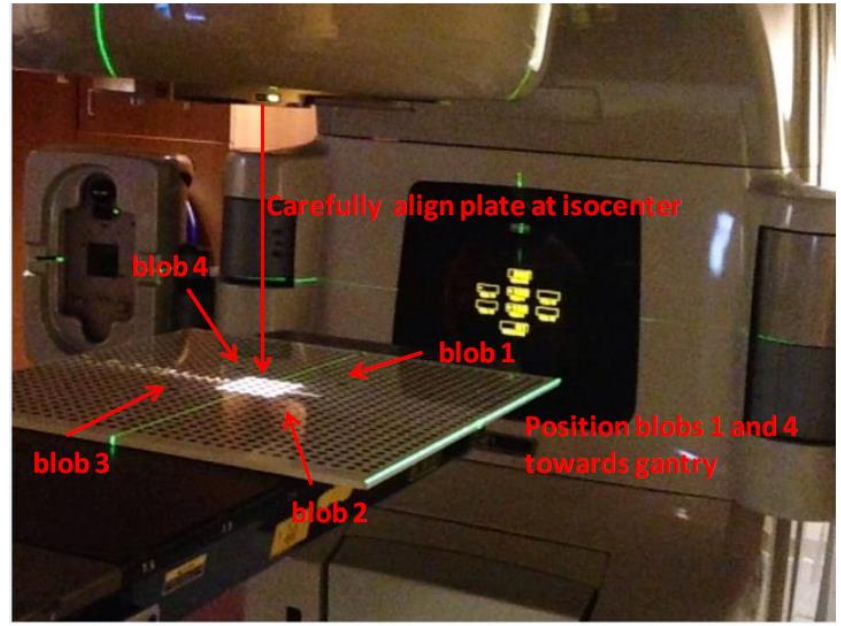
- **Equipment**
  - Representative clinical anatomical phantom with implanted reference marker(s)
  - Dynamic radiation delivery phantom
- **Methodology**
  - End-to-End dynamic localization and delivery
    - Scan phantom in CT
    - Create representative plan centered around marker
    - Position with SGRT system (without IGRT system)
    - Deliver with representative breathing pattern (i.e. DIBH, Exhale etc)
  - Results provide overall system error
    - Should be <1mm (or as specified by vendor)



ONGOING QA

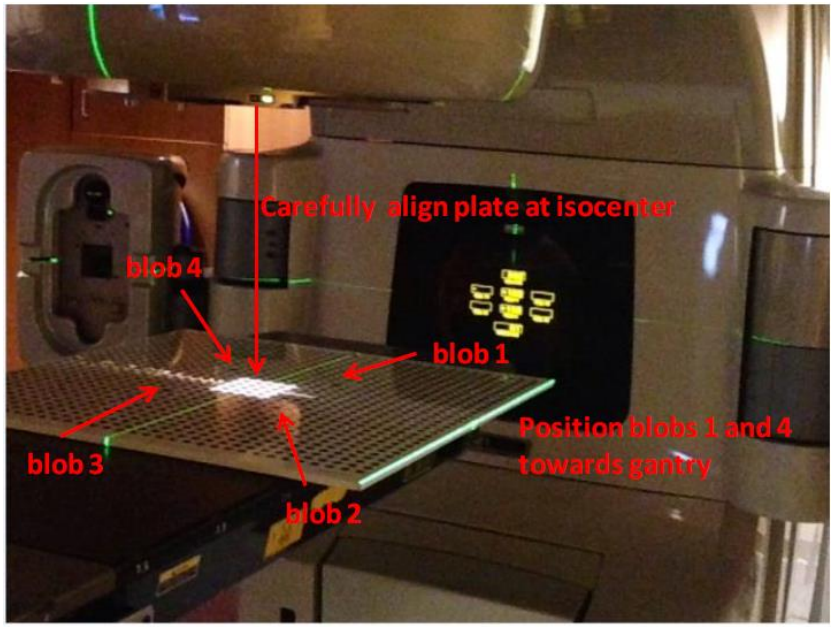
- Daily QA
  - Safety Check
    - Interlocks and clear field of view for all mounted cameras
  - Static localization
    - Daily QA phantom positioned at isocenter and can track movement to isocenter from offset
    - 2 mm / 1 mm

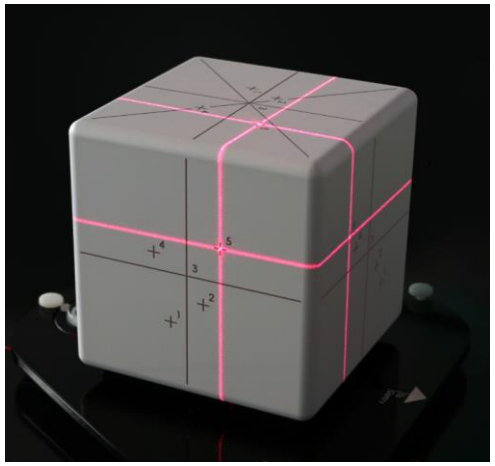


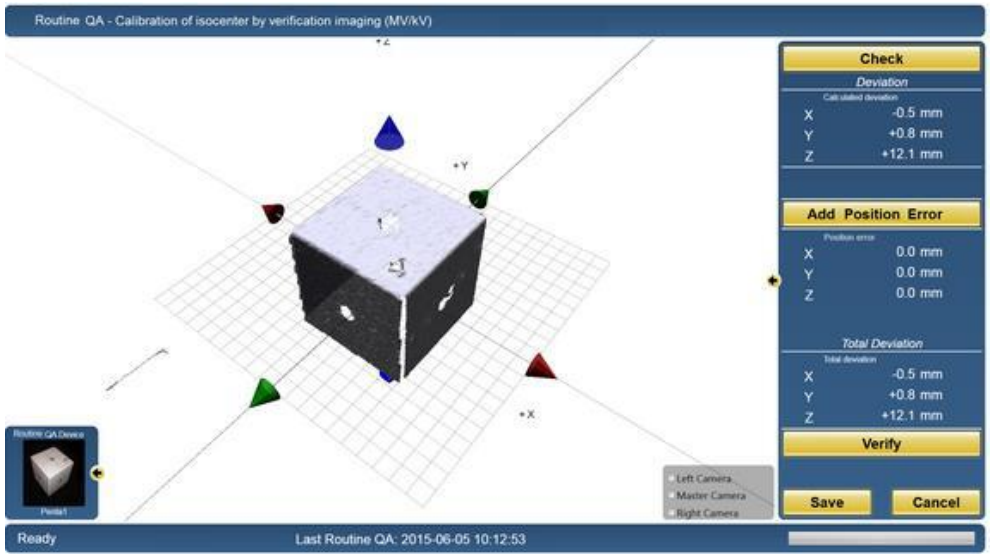


ONGOING QA

- Monthly QA
  - Safety
    - Machine interface: Gating termination, couch motion communication
  - Static localization E2E
    - Localization test based on radiographic analysis (i.e., hidden target)
    - TG-147: 2 mm Conv;1 mm SRS/SBRT
    - Vendor specific workflows







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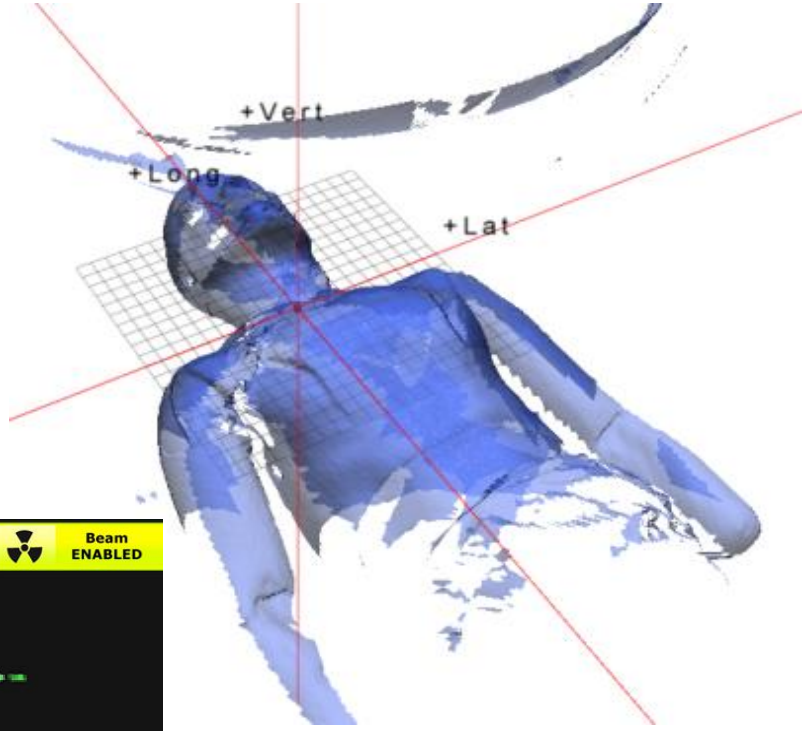
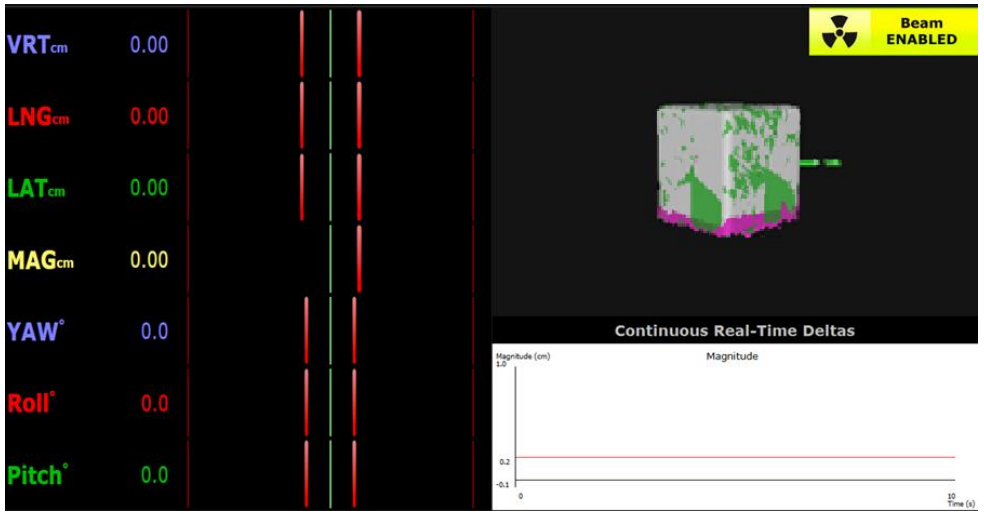
ONGOING QA

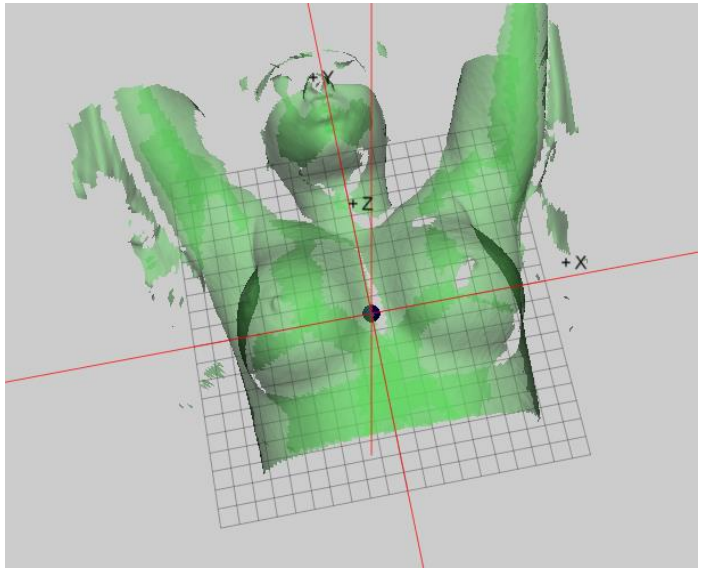
- Annual QA
  - Temporal drift assessment
  - Static localization E2E
  - Dynamic delivery E2E
  - Workflow and policy review

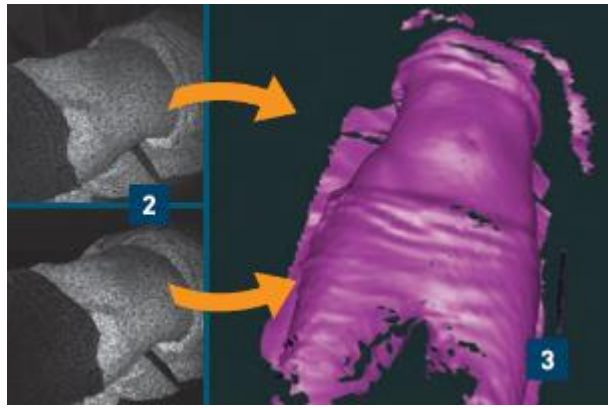




ADDITIONAL CONSIDERATIONS FOR SI

- Evaluation of skin tone effect
- Phantom Selection
  - Phantom finish, color and shape
  - Representative of desired clinical treatment sites
- Impact of Registration Accuracy and ROI Selection on Localization Accuracy
  - The registration accuracy should be evaluated at the time of acceptance and commissioning and, at a minimum, be accurate to the minimum accuracy specified by the vendor.
  - Proper ROI selection should include, at minimum, the area being treated and any surrounding areas that could manipulate the treated area





ADDITIONAL CONSIDERATIONS FOR SI

- Camera settings optimization
- Mask optimization for SRS
- Patient selection criteria
  - Position only
  - Monitor only
  - Position and monitor
  - Position, monitor and gating
- Patient education

New recommendations coming from TG-302!

THANK YOU!