

3D Surface Imaging for SRS

Vision RT – Users Meeting 2015
(User Workshop on SRS)
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Philips Brilliance CT - Big Bore Oncology

http://www.healthcare.philips.com/main/products/ct/products/ct_brilliance_big_bore_oncology/

Vision RT GateCT

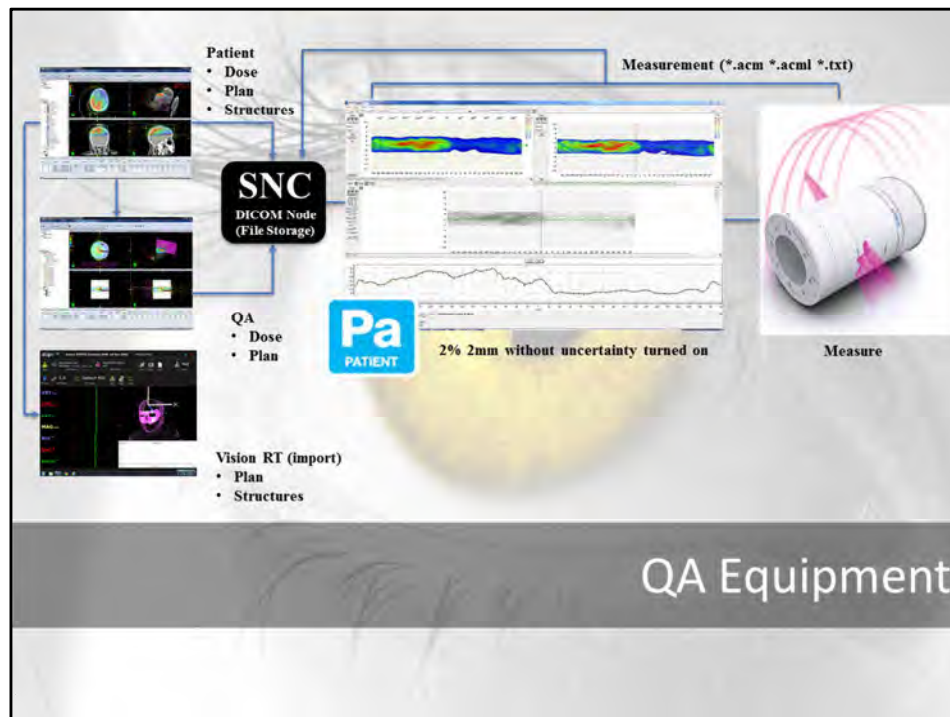
http://www.visionrt.com/products_solutions/gatect

Lap Dorado Lasers

http://www.lap-laser.com/fileadmin/lap-laser/documents/downloads/pdf/brochures/DORADO_bro_aa_1-1_2015-04-09_21x28_Web.pdf

Carinaiso

<http://www.lap-laser.com/medical-systems/patient-marking/laser-control-systems/carinaiso/>



QA Program Equipment

SNC 3DS system for scanning

<http://www.sunnuclear.com/medPhys/dosimetry/3dscanner/3dscanner.asp>

ArcCheck Patient 6.6

<http://www.sunnuclear.com/medPhys/patientqa/arccheck/arccheck.asp?tab=4#TabbedPanels1>

MapCheck2 Patient 6.6

<http://www.sunnuclear.com/medPhys/patientqa/mapcheck2/mapcheck2.asp>

StereoPHAN

<http://www.sunnuclear.com/medPhys/machineqa/stereophan/stereophan.asp>

IC Profiler

<http://www.sunnuclear.com/medPhys/machineqa/icprofiler/icprofiler.asp>

Profiler2

<http://www.sunnuclear.com/medPhys/machineqa/profiler2/profiler2.asp>

ImagePro Phantoms

<http://www.sunnuclear.com/medPhys/machineqa/imagepro/imagepro.asp>

Lucy

<http://www.standardimaging.com/phantoms/lucy-3d-qa-phantom/>

MIMI Phantom

<http://www.standardimaging.com/phantoms/mimi-phantom/>

DoseLab Pro

<http://www.mobiusmed.com/doselab/>

Atlas

<http://www.sunnuclear.com/medPhys/routineqa/atlas/atlas.asp>

Detectors

Edge (scanning diode)

<http://www.sunnuclear.com/medPhys/dosimetry/edgedetector/edgedetector.asp>

PTW TN31010 (0.125cc)

http://www.ptw.de/semiflex_chambers0.html

PTW TN31014 (0.015cc)

http://www.ptw.de/pinpoint_chambers1.html

PTW TN30013 (Farmer)

http://www.ptw.de/waterproof_farmer_chamber0.html



TrueBeam 2.0

<http://www.variantruebeam.com/>



Vision RT AlignRT

http://www.visionrt.com/products_solutions/alignrt

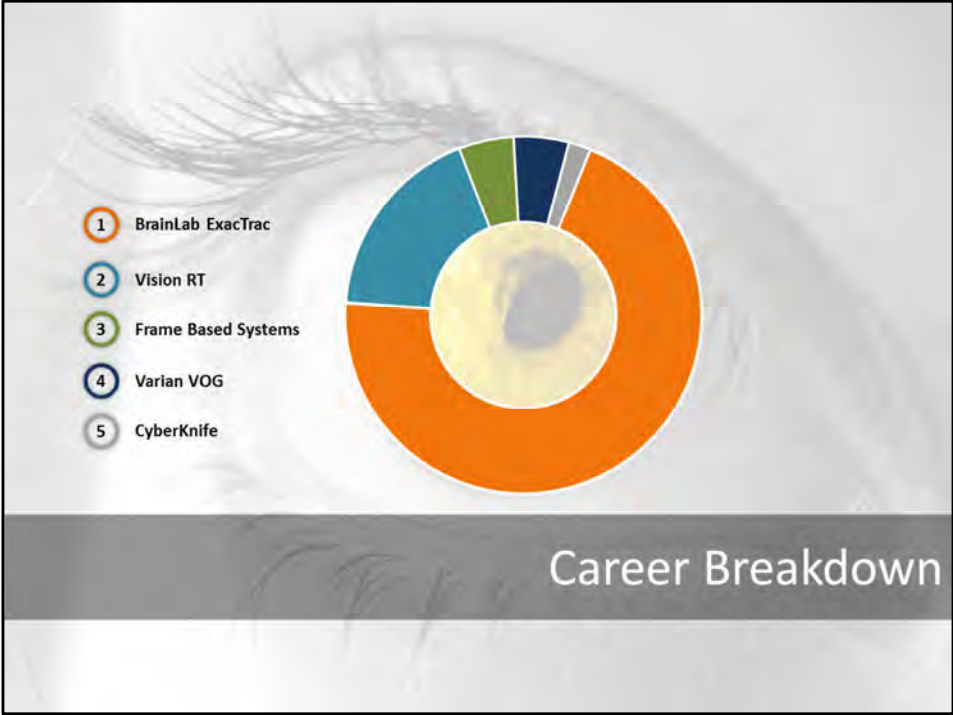


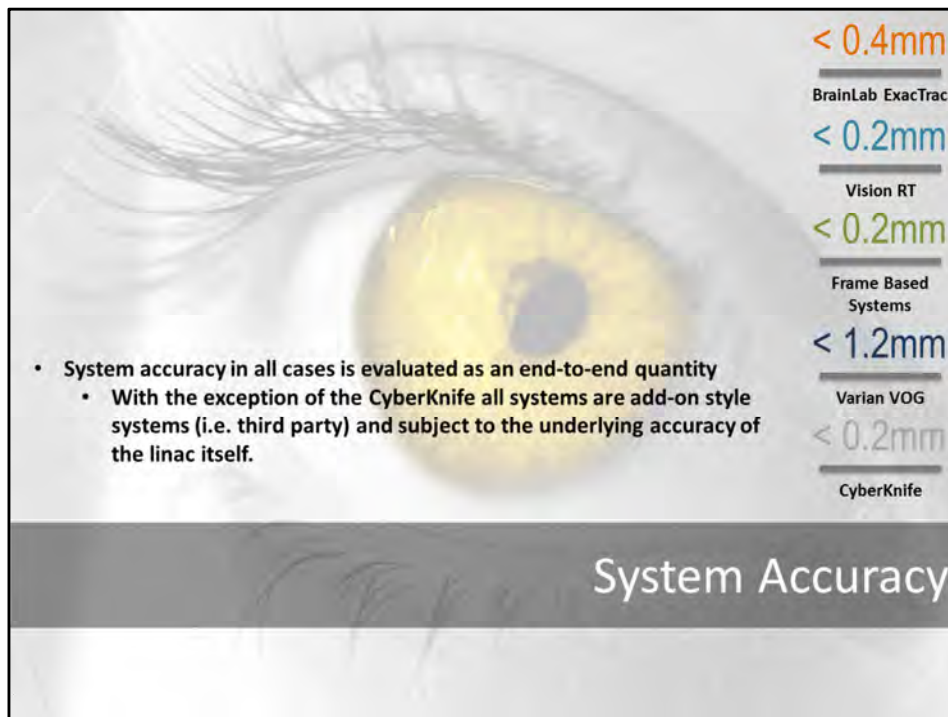
Orfit AIO Immobilization System

<http://www.orfit.com/en/the-aio-solution/>

Vision RT w/ 3Degree head adjuster and open-faced mask

http://www.visionrt.com/products_solutions/srs





Comparison of various systems' accuracy over the years

- System accuracy in all cases is evaluated as an end-to-end quantity
- With the exception of the CyberKnife all systems are add-on style systems (i.e. third party)
 - Third party systems are subject to the mechanical systems they are attached to (i.e. linacs)
 - Total accuracy values are therefore end-to-end values utilizing all of the components that make up the end-to-end system.



Most common places for errors in an SRS program (WHO survey – many other papers break this out in greater detail)

- Commissioning and Planning
- Implementation
- Process

Overall Program Development Resources (Google these – all free for download all good for the entire team to read or at least be familiar with)

- 2011 ASTRO White Paper on Quality and Safety Considerations in Stereotactic Radiosurgery and Stereotactic Body Radiation Therapy
- 2012 ASTRO Safety is No Accident
- 2013 ACR SRS Practice Guidelines (Reviewed every 4 years)
- AAPM TG Reports
 - TG-42 (Report on SRS)
 - TG-142 (Report on Linac QA with SRS specific tolerances)
 - Practical Guide to TG-142 QA (Jimmy Jones / Mobius)
 - <http://medphysfiles.com/index.php?name=Downloads&get=106>
 - TG-101 (Report on SRS and SBRT)
 - TG-135 (CyberKnife specific but has good information)
 - TG-147 (Specific to nonradiographic positioning systems)

Implementation Resources (check with vendors for contact information of reference sites and/or training schedules)

- Vendor Training (Essential for new equipment)
- Vendor onsite support
 - Ideal to run through process with entire team with vendor
 - Can be used to identify holes and refine Policies and Procedures
 - Clears up some miscommunications and misconceptions on use
 - Scheduling during first case is always helpful (if possible)
- Learning from an experienced site
- Proctoring with a site
 - Peer review of first few cases
 - Data validation
- Dedicated training courses and users meetings (what we are doing right now)

Talks and Meetings (Many other examples)

Dr Sonja Dieterich (UC Davis) – 2015 AAPM Summer School Talk

Dr Ryan Foster (UT Southwestern) – 2015 AAPM Summer School Talk

Dr Indrin Chetty (Henry Ford Health System) – Talk on Small Field Dosimetry

Dr. Timothy Solberg (U Pen) – Talk on Small Field Dosimetry and SRS review

Books

Statistical Process Control for Health Care – by Marilyn K Hart and Robert F Hart

- Very simple introduction to SPC and some useful methods for checking your data (is it suitable for SPC)
- Some good examples

Introduction to Statistical Process Control - by Douglas C. Montgomery

- More rigorous presentation of SPC

From Wikipedia:

The success of SPC relies not only on the skill with which it is applied, but also on how suitable or amenable the process is to SPC. In some cases, it may be difficult to judge when the application of SPC is appropriate.

Programming

Python – <https://www.python.org/>

- Extremely easy to learn language with lots of online learning resources and very nice scientific and array based mathematical libraries
 - Numpy
 - SciPy
 - Pydicom – DICOM library (usually not included with most installs below but easy to install)

All inclusive distributions for science and engineering

- Anaconda - <https://store.continuum.io/cshop/anaconda/>
- Python xy - <https://code.google.com/p/pythonxy/>
- Enthought Canopy - <https://store.enthought.com/>



Commissioning

- Dosimetry
 - TG-106 Setup for scanning system very important
 - Know your system (be aware of software corrections in the background)
 - Detector selection
 - Important to understand detector characteristics
 - Important if using FFF
 - OF for very small fields (recommend comparison with multiple institutions and published data)
 - Dr Indrin Chetty (Henry Ford Health System) Small Field Dosimetry Talk
 - Dr Timothy Solberg (U Pen) Small Field Dosimetry and SRS review Talk
 - IROC (RPC) publications on small field dosimetry
 - Cones
 - Film
 - Chamber and Diode selection
 - Curve fitting can be used as a sanity check (Modified Cunningham Equations)

Daily Quality Management (TG-142)

- Daily output on morning check device
- Flatness and Symmetry
- Energy Checks

Monthly Quality Management (TG-142 and TG-51)

- TG-51 output verification (or similar output verification)
- Flatness and Symmetry

- Energy Checks (Profile Constancy)
- Output Constancy with Gantry Angle
- Output Constancy with Dose Rate
- Output Constancy with Gating



Commissioning

- Mechanicals
 - Vision RT Isocenter Cube is a good (but not always the best) choice due to its symmetry (sometimes a good characteristic though)
 - Things to check
 - Couch
 - Walkout (See ***Couch Walkout with AlignRT*** slide)
 - Repositioning
 - Couch 's ability to correct for setup (6DoF vs 4DoF with 3D head holder)
 - With combinations of systems (i.e. non-6DoF couches) beware of double corrections
 - Spoke films
 - Winston-Lutz testing
 - Jaws (WL test as a baseline)
 - MLCs (WL test as compared to Jaws to track offset)
 - Cones (WL test as compared to Jaws to track offset)
 - Note where offsets and couch walkout result in unfavorable individual values not just 3D target position
 - Example: It may be better to perform a sagittal arc at a 270 degree couch kick rather than at 90
 - Alternating collimator angles during planning for small targets can reduce MLC offset effects.
 - SRS Interlocks (if applicable)
 - Collision Interlocks (if applicable)

Daily Quality Management (TG-142)

- Field Size (Jaw settings)
- Lasers
- Dynamic Jaws
- MLC (Picket Fence at cardinal gantry angles Ling et al)**
- Winston-Lutz (using end-to-end phantom on morning of SRS or SBRT cases)
- Stereotactic Interlocks (lockout – if applicable)

**Note: For multifocal single isocenter SRS pans perform monthly Ling et al tests from Monthly QM if it has been more than a week since last set

Monthly Quality Management (TG-142)

- MLC (Picket Fence at cardinal gantry angles Ling et al)
- MLC VMAT Picket Fence (Ling et al)
- Gantry Speed and Dose Rate (Ling et al)
- MLC Leaf Speed (Ling et al)
- Field Size (Jaw settings)
- Lasers
- Dynamic Jaws
- Cone Centering (Winston-Lutz)
- Stereotactic Interlocks (lockout)



Commissioning Imaging

- Imaging system
 - System Acceptance and Checkout
 - Vendor supplied procedures to demonstrate functionality
 - Site specific testing to validate functional performance
 - TG-142, TG-66 and possibly some TG-147 (if applicable)
 - Items to check or verify (Catphan 504 phantom)
 - Scaling
 - Geometric Distortion
 - Spatial Resolution
 - Uniformity
 - Low contrast detectability
 - High Contrast
 - Contrast to noise ratio (CNR)
 - HU
 - Slice thickness
 - Imaging modes and filter settings
 - Gating tied to imaging (if applicable)
 - Automated couch positioning and repositioning interconnectivity
 - SRS or system specific calibrations (e.g. IsoCal from Varian)
 - **Understand how software works**
 - Are corrections mechanical or software based (e.g. IsoCal different on C3 machine vs TrueBeams)
 - Does it need to be done routinely?

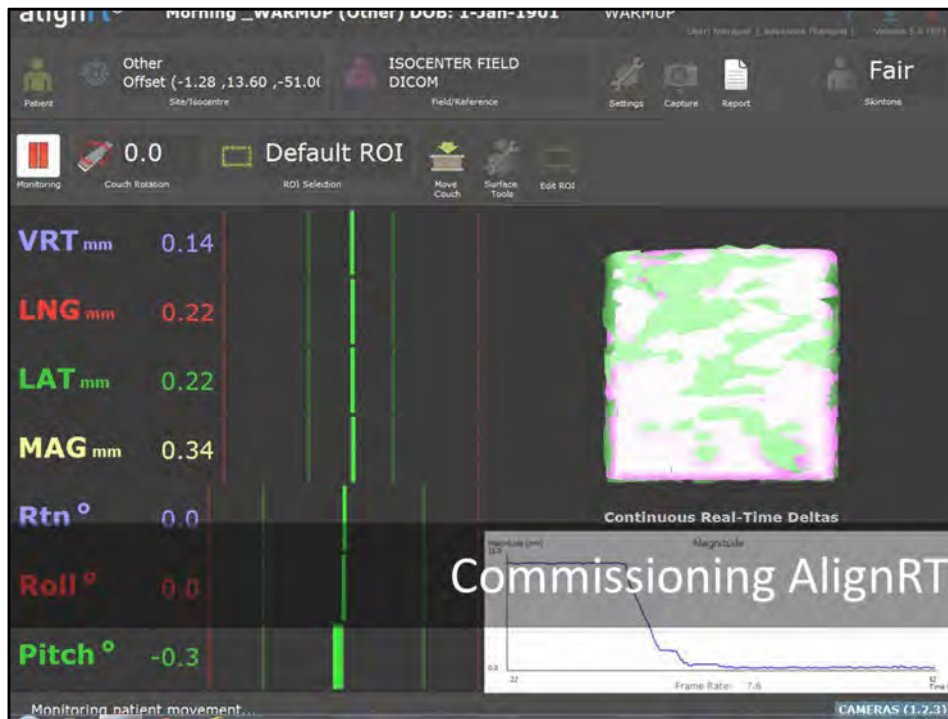
- How is it affected by other calibrations of the system?
- Work with therapists on functional characteristics (best done in an end-to-end manner)
 - Understand how any imaging filters work
 - Work through fusion tools
 - Work through acquisition process
 - Recommend having staff be part of (some not all) end-to-end hidden target tests

Daily Quality Management (TG-142 / TG-147)

- MV / kV / CBCT / AlignRT isocenter coincidence
- Remote positioning and repositioning

Monthly Quality Management (TG-142 / TG-147)

- CBCT
 - Scaling
 - Geometric Distortion
 - Spatial Resolution
 - Uniformity
 - Low contrast detectability
 - High Contrast
 - Contrast to noise ratio (CNR)
 - HU
 - Slice thickness
- MV / kV / CBCT / AlignRT isocenter coincidence
- MV / kV Image Quality



Commissioning AlignRT

- VRT System setup for SRS
 - System Acceptance and Checkout
 - Vendor supplied procedures to demonstrate functionality
 - Site specific testing to validate functional performance
 - TG-147 and TG-142 testing and tolerance specs
 - Safety
 - Static Localization (Hidden target tests)
 - Dynamic Localization (System response time to repositioning)
 - Accuracy and Stability
 - Documentation and Data Transfer
 - Partial obstruction tests
 - Machine Integration
 - Safety
 - Load plans with multiple isocenters and try to select incorrect isocenters in AlignRT
 - Test known error conditions
 - Gating
 - Remote couch motions
 - **Important to understand how this is accomplished to avoid errors**
 - Isocenter coincidence with all other imaging systems
 - Can use phantom end-to-end test or isocenter calibration with kV imaging

- Isocenter Cube Calibration for SRS
 - Understand how software works
 - Field center based on rad field vs imager center
 - Image center option is new (still investigating)
 - Currently using field center
 - Check for systematic errors by rotating geometry and checking for shift migration
 - Does it need to be done routinely?
 - How is it affected by other calibrations of the system?
 - Make sure you QA system before just jumping into calibration
 - Verify Jaw settings if you are using field center based calibration
 - Verify central pixel for imager center calibration
- Work with all staff members using this function of the software (usually just physics)

Daily Quality Management (TG-147)

- Daily QA (plate verification test of cameras – vendor recommendation)
- MV / kV / CBCT / AlignRT isocenter coincidence
- Remote positioning and repositioning
- Beam gating interface (MMI) verification
- Reference Imaging
- ROI transfer
- Obstruction verification

Monthly Quality Management (TG-147)

- Monthly Calibration
 - Standard and Raised Plate
- Daily QA (plate verification test of cameras – vendor recommendation)
- MV / kV / CBCT / AlignRT isocenter coincidence
- Remote positioning and repositioning
- Beam gating interface (MMI) verification
- Reference Imaging
- ROI transfer
- Obstruction verification



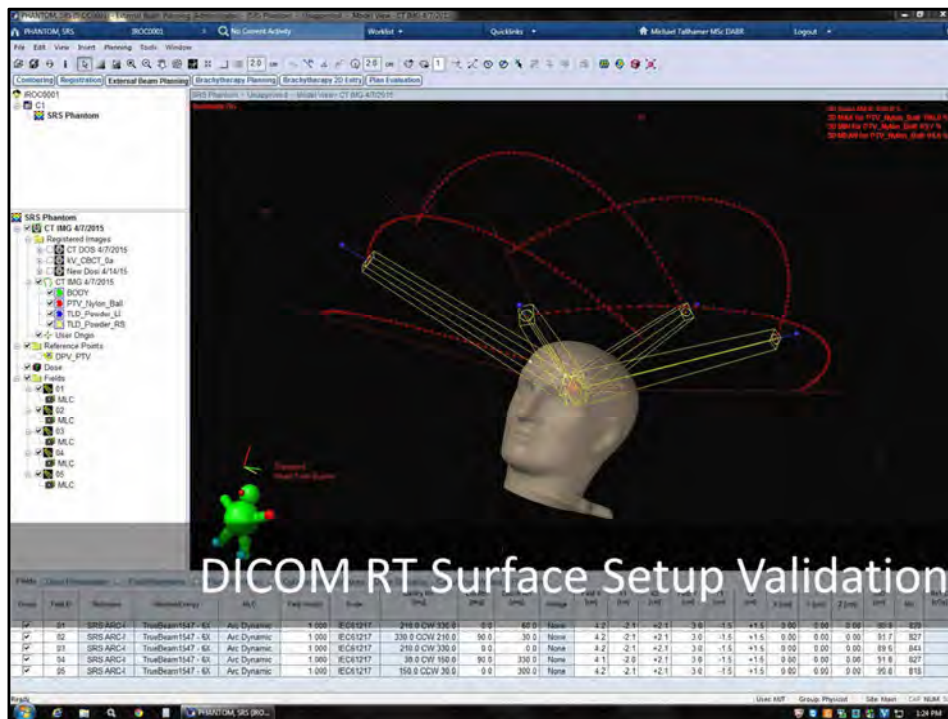
CT Simulation

- System Acceptance and Checkout
- Vendor supplied procedures to demonstrate functionality
- Complete TG-66 and TG-53 (data transfer portions) testing
 - Items to check or verify (Catphan 504 phantom or vendor supplied phantoms)
 - Scaling
 - Geometric Distortion
 - Spatial Resolution
 - Uniformity
 - Low contrast detectability
 - High Contrast
 - Contrast to noise ratio (CNR)
 - HU
 - Slice thickness
 - Transfer to TPS should be verified with a well defined phantom geometry
 - Many commercially available phantoms
 - Isocenter cube phantom from Vision RT is a good tool for this.
 - See



Contouring...Yeah Contouring...

- Not something you can use statistics to effectively change.
- Peer reviewed papers have shown on blind comparison that contouring can be highly variable
 - In SRS cases this is usually associated with OARs like the optic chiasm and other difficult neuroanatomy in, around, or near the treatment site
 - Targets are typically easy to determine from MRI
- Contour "quality" is variable but collaboration between team members can have positive impact
 - I have been in departments where personalities prohibit this
- Just remember precision can be lost at any stage in the process not just on the delivery side
 - You can measure with a micrometer and cut with a laser but if you mark it with chalk the precision is suspect



The “Body” contour can effect treatment setup using the DICOM RT reference surface

- Now that we are using surface imaging to align and track patients during delivery, we need to understand the affects different methods of surface contour selection have on the overall patient setup accuracy.
- Since this process takes place during planning different methods of surface detection (i.e. auto-contouring, threshold detection, manual contouring) should be evaluated.
 - **Manual contouring for patient surface is very rare and should not be used through the anticipated ROI region**
 - Auto-contouring is typically done through some type of threshold detection algorithm so these options are usually the same.
- This is something we can look at statistically to see how much it will effect our setups

Shifts from DICOM RT Setup (selection of TPS threshold)

- Push phantom with variable surface skin tones through the system to determine effects of TPS surface contour threshold and skin tone on patient setup
- TPS thresholds for surface detection can change the accuracy of the initial setup of the patient by placing the DICOM surface “inside” the surface of the patient.
 - Variability in the initial setup leads to variation in the expected shifts from the AlignRT DICOM RT surface setup to final imaging setup.
 - This makes detecting setup errors more difficult and less likely to stand out at the time of treatment
- Standardizing thresholds for surface detection leads to stable (note not better) initial setups.

Threshold determination

- Run a phantom through the system multiple time using different thresholds (-550HU to -150HU) to detect

the surface contour

- Repeatedly position phantom using the resulting surface contours using different staff and differing skin tone settings
- Followed initial positioning up with CBCT localization of the phantom and recorded difference (shifts) from AlignRT setup to CBCT setup
- We determined -350HU had the lowest variation (smallest standard deviation) across all dimensions.
 - Expected mean vertical shift from phantom testing 0.1cm (standard deviation 0.02)
 - Expected mean lateral shift from phantom testing 0.03cm (standard deviation 0.01) – lower standard deviation and mean offset assume to be due to relative symmetry of human face along the long axis.
 - Expected mean longitudinal shift from phantom testing 0.06cm (standard deviation 0.02)
- Review of first 30 SRS fractions on actual patients showed
 - Average vertical shift 0.97cm (standard deviation 0.017)
 - Average lateral shift 0.035cm (standard deviation 0.011)
 - Average longitudinal shift 0.064cm (standard deviation 0.023)



No I don't see these patients

- Probably the most asked question
- I have never had a patients facial expressions or features adversely effect a setup
- Mostly because when I ask them to lay still and close their eyes...they do
- Though we use an open face mask we still focus on immobilization while making a mask.
- We don't include mouth or eyes in ROI (will see example on later slide)



A Quality Management Program should address what you plan on treating.

- What types of treatments are you planning on delivering
 - Single isocenter located in a single target
 - Multiple isocenter plans (moving from isocenter to isocenter during the course of treatment)
 - Single isocenter multifocal targets (multiple metastases single isocenter)
 - Hybrid combinations of the above
- Expectations and Quality Management Program
 - Quality Assurance metrics
 - Division of responsibilities (Who does what?)
 - How much can you automate to avoid variation and error?
 - Standard plans for Daily, Weekly, and Monthly system checks
 - How will you determine quality of the system as a whole
 - Comparing patient metrics to phantom metrics
 - Following patients
 - What are the known geometric limits

Displacement of contour center (mm)						Geometric Overlap for a 6mm met					
Distance from Isocenter (cm)	Rotation in degrees					Distance from Isocenter (cm)	Rotation in degrees				
	1	2	3	4	5		1	2	3	4	5
1	0.17	0.35	0.52	0.70	0.87	1	96%	91%	87%	83%	78%
2	0.35	0.70	1.05	1.40	1.74	2	91%	83%	74%	66%	58%
3	0.52	1.05	1.57	2.09	2.62	3	87%	74%	62%	50%	39%
4	0.70	1.40	2.09	2.79	3.49	4	83%	66%	50%	35%	23%
5	0.87	1.75	2.62	3.49	4.36	5	78%	58%	39%	23%	10%
6	1.05	2.09	3.14	4.19	5.23	6	74%	50%	29%	12%	2%
7	1.22	2.44	3.66	4.89	6.11	7	70%	42%	20%	5%	0%
8	1.40	2.79	4.19	5.58	6.98	8	66%	35%	12%	1%	0%
9	1.57	3.14	4.71	6.28	7.85	9	62%	29%	6%	0%	0%
10	1.75	3.49	5.24	6.98	8.72	10	58%	23%	2%	0%	0%
11	1.92	3.84	5.76	7.68	9.60	11	54%	17%	0%	0%	0%
12	2.09	4.19	6.28	8.38	10.47	12	50%	12%	0%	0%	0%
13	2.27	4.54	6.81	9.07	11.34	13	46%	8%	0%	0%	0%
14	2.44	4.89	7.33	9.77	12.21	14	42%	5%	0%	0%	0%
15	2.62	5.24	7.85	10.47	13.09	15	39%	2%	0%	0%	0%
16	2.79	5.58	8.38	11.17	13.96	16	35%	1%	0%	0%	0%
17	2.97	5.93	8.90	11.87	14.83	17	32%	0%	0%	0%	0%
18	3.14	6.28	9.42	12.56	15.70	18	29%	0%	0%	0%	0%
19	3.32	6.63	9.95	13.26	16.58	19	26%	0%	0%	0%	0%
20	3.49	6.98	10.47	13.96	17.45	20	23%	0%	0%	0%	0%

Calculated Geometric Limits
Simple Geometry (Multiple Spherical Targets – 1 Isocenter)

Multifocal Single Isocenter Plans (Example)

- Multifocal single isocenter plans are getting more popular
 - Some TPS vendors are now advocate auto fusion, auto contouring and automated treatment planning
 - Not many recommendations on adequate quality assurance measures for such treatments
- Plans with variable number of targets with large variations in distance from isocenter and target size can introduce issues simply based on the geometry of the targets and their relative position to one another
- Small rotational changes can result in large linear distance changes for targets far from isocenter
- Linear displacements have different effects on total geometric overlap between original target position and new target position for targets of different sizes
- It is relatively straight forward to calculate geometric overlap tables for targets of different sizes assuming spherical targets using a programming language like Python or commercial tool like Excel
 - First linear displacements are calculated as a function of rotational offset and distance from isocenter
 - These distances “d” are then used to compute the geometric intersection of an ideal spherical target with a centroid displacement of “d”
 - As would be expected the largest consequences are for small targets far from the isocenter
- Since rotations are linear operations it is straight forward to predict the consequences of rotations around more than one axis
- Linear displacement table as a function of distance from isocenter and angular displacement can be used in margin determination.
- An understanding of this relationship is important during TPS image fusion, fusion review, contouring, isocenter placement, planning and image fusion at the time of delivery.
- Independent multifocal Winston-Lutz tests can be used but are not supported in any known commercially

available software.

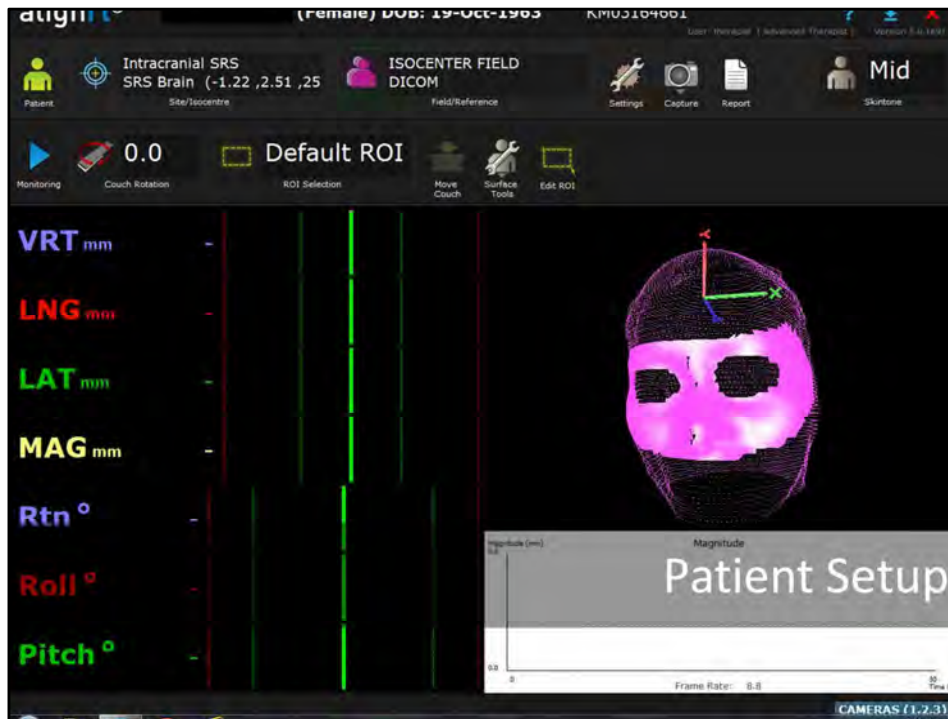
- You can use a 3D conformal arc off axis to do a Winston-Lutz test with current software if you aren't prone to program up one yourself.



Practice Makes Perfect

Knowing your system accuracy and limitations isn't enough to overcome poor process on patients

- Phantoms are very reliable patients and great for assessing the system but our patients aren't like our phantoms
- Have to strike a balance
 - Need enough surface for reliable ROIs
 - Immobilization is still a good thing (and sometimes needed)
 - Motor cortex mets (tics and tremors)
 - Severe claustrophobia
 - Mild dementia
 - In all reality most patients are very easy but process stability and consistency avoids errors
 - **Masks with enough surface of their own can be utilized to do pre-treatment collision checks by placing a QA ROI on the mask so that the mask can be setup without the patient allowing clearance checks to be completed**
- Just because the vendor recommends mask making in a certain way or the box has a picture on it that doesn't mean that is the correct way for your patients or process
 - Experiment to see how much open area is needed and how much you are willing to accept
 - People who will be making the masks should be the ones practicing (not just physics)
 - If people involved are willing I always recommend everyone be the volunteer



Practice Makes Perfect (Continued)

Not all end-to-end testing requires beam on time - Division of responsibilities (Who does what?)

- Take your practice masks to the machine and perform setups with your staff
 - Use base phantom plans as a practice patient with different isocenters to select starting point ROIs
 - Create secondary fields for the different isocenter plans using the volunteers initials as the name of the field
 - Do a rough (very rough) alignment of the volunteer in their mask using the phantom DICOM RT surface
 - Just looking for a relative isocenter location
 - Once "aligned" select the volunteer's field in the dropdown list and take a reference image
 - Select ROI using the ROI tools
 - Monitor the volunteer and test the ROI by rotating the gantry/couch and partially blocking the cameras
 - If everything checks out then mark the mask (as best you can) for future reference and practice sessions.
 - Future sessions can use the last reference image as a pseudo DICOM setup surface
 - The head adjustments can then be used to fine tune the volunteer just like a regular patient
 - The marks can serve as a secondary verification of final setup with AlignRT on subsequent alignments

****WARNING:** Do NOT CT, CBCT or image your volunteers in any way



Practice Makes Perfect (Continued)

Some end-to-end testing requires beam on time - Division of responsibilities (Who does what?)

- IROC SRS Head Phantom - <http://rpc.mdanderson.org/RPC/home.htm>
 - Good overall system check
 - From past experience often times done end-to-end by a physicist
 - Recommended to be done using the entire team
 - Requires a good process in place before you start
 - No treatment imaging for alignment is mentioned in the instructions
 - Have received different responses upon inquiry but does say “treat as you would a patient”
 - AlignRT setup considerations
 - Clear surface is not conducive to good AlignRT surface tracking
 - Simple fix is to use standard masking tape to cover the surface
 - Surface selection statistics are helpful to know ahead of time
 - How much difference between DICOM RT surface setup and CBCT alignment can be expected
 - Simple workaround is to CBCT the phantom setup on the table with the imaging insert loaded
 - Align the phantom using the CBCT and take a new reference image with AlignRT
 - Remove phantom from couch and load dosimetry insert and re-align to reference image
 - Treat the phantom without the need for a CBCT since it was done earlier



Vendor System Checkout and Calibration

Vendor Recommended Daily System Checkout (Daily QA)

Vendor requires Daily QA prior to use.

Procedure

- Calibration Plate is aligned to isocenter using either the room lasers or crosshairs and ODI
- Room conditions should be the same as those used for the monthly calibration
 - Dimmer switches, ceiling fixtures and work light conditions used for calibration (and subsequent Daily QAs) should mimic those typically used during treatment and monitoring of patients
- Daily QA workspace can be launched from the System Maintenance screen within the software.
- The user is then walked through a series of images used in the Daily QA checks within the software
- The position of the isocenter is determined based on the setup and detection of the calibration plate features.
- The RMS deviation is then reported to the user
- The current version of the software allows you to set the threshold for the RMS deviation from 0.1mm – 1.0mm in 0.1mm increments.
- The software will then allow you to print a Daily QA report for documentation purposes.
- Mean RMS values for the cameras is 0.25mm (reported in 0.1mm increments)

Vendor Recommended Monthly System Checkout (Monthly Calibration)

Vendor recommends a monthly calibration but we have found that the camera calibration is very stable via statistical tracking of the Daily QA report values. We have since gone to recalibrating on an as needed basis.

Procedure

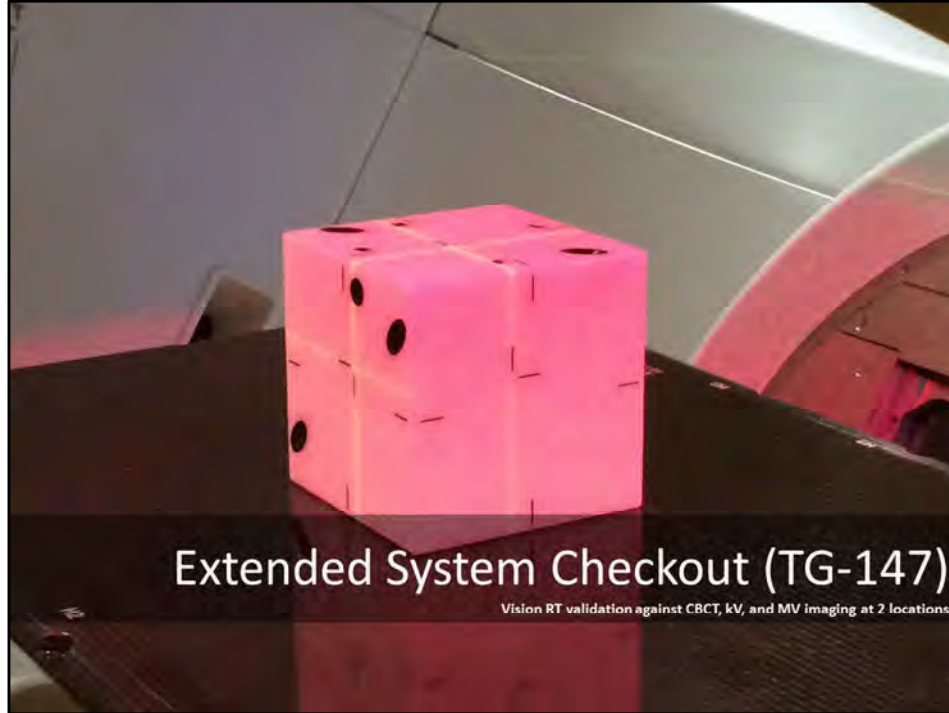
- Calibration Plate is aligned to isocenter using either the room lasers or crosshairs and ODI

- Dimmer switches, ceiling fixtures and work light conditions used for calibration (and subsequent Daily QAs) should mimic those typically used during treatment and monitoring of patients
- Monthly Calibration workspace can be launched from the System Maintenance screen within the software.
- The user will be warned that the previous monthly calibration images will be invalidated if they proceed and must confirm yes or no that they wish to proceed.
 - You will not be warned that any associated Isocenter Calibrations will also be invalidated but this will in fact happen if you proceed.
- If you select “Yes” you will be walked through a simple calibration procedure
- The position of the isocenter is determined based on the combination of setup and detection of the calibration plate features as well as some intervention on the behalf of the user.
- You can follow-up the Monthly Calibration with a Daily QA just to verify the new calibration is in effect.
- If you are using the system for SRS you will need to proceed to Isocenter Calibration (below)

Vendor Recommended SRS Isocenter Calibration

- The Isocenter Cube phantom is aligned to the isocenter using an ideal geometry
- Dimmer switches, ceiling fixtures and work light conditions used for calibration should mimic those typically used during treatment and monitoring of patients
- Isocenter Calibration workspace can be launched from the System Maintenance screen within the software.
 - You will be required to have the correct security rights to complete an Isocenter Calibration
- Isocenter is completed by taking a number of radiographic images of the Isocenter Cube at the setup position and completing the radiographic analysis of those images
 - Recommend setting up a standard plan that can be used to acquire the above images (minimum 4 images at cardinal gantry angles)
 - It is assumed the appropriate imaging and mechanical checks per TG-142 have been completed prior to Isocenter Calibration
 - If using Field Center calibration it is recommended to use a symmetric jaw setting and obtaining the 4 cardinal images at minimum of 2 different collimator rotations (0.0, 90.0 or 270.0 degree rotation IEC61217) to verify any offsets prior to apply an isocenter calibration.
 - Image Center isocenter calibration is new in the most current version of the software and is still being evaluated by our clinic.
- Once images are acquired they are place in a configure folder location at which point they can be processed by the software
- The analysis can be applied and resulting shifts should be verified (Winston-Lutz is recommended) prior to recalibrating isocenter.
- Once Isocenter Calibration is completed a Daily QA should be run for verification purposes.

Vendor training is recommended and required prior to engaging in any of the above procedures



TG-147 Testing

- TG-147 states TG-142 tolerances for SRS localization should be met by the system (i.e. 1mm for SRS applications)
- It also states, *“Additionally, the ability to accurately use the localization system to move a target a known distance should be evaluated on acceptance and monthly thereafter, as well as after any equipment change, and more frequently as recommended by the vendor.”*
- The interfaces to the machine such as MMI interfaces should also be checked on regular basis

The official recommendation as to the frequency of any one of these test is listed as at Acceptance / Commissioning and monthly thereafter along with the vendor recommended tests and frequencies. We have determined that the tests listed in the task group are easily accomplished on a daily basis by the therapists and can be run by a physics monthly. The process adds approx. 5-7min to our previous Daily QA procedures.

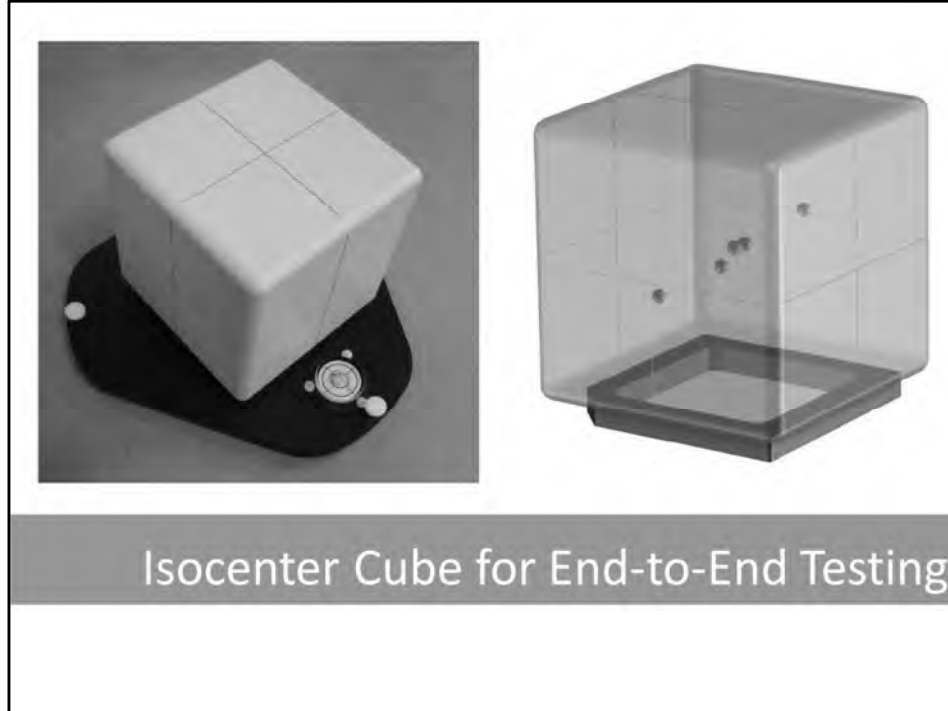
TG-147 Daily QA is accomplished using a standard DICOM RT plan with 2 isocenters pushed to both AlignRT and the TrueBeam

Procedure

- Therapists open a Daily Imaging DICOM RT plan in Machine QA mode on the machine
- The MMI interface prompts the used to open the patient in AlignRT
- Therapists setup and align the MIMI phantom to the offset (non-central) isocenter using an index bar and the room lasers
- Once setup the offset isocenter is selected in the open AlignRT Daily QA patient.
- The phantom is monitored and offsets are documented (should be <1.5mm)
- Once the offsets from the phantom setup are recorded and the setup to the marked isocenter is

- confirmed a new reference image is taken to zero out the setup position
- The therapists then CBCT the phantom and reposition the phantom to the central sphere using the CBCT system's fusion and remote motion capabilities (a known offset to the documented center of the phantom).
 - Shifts magnitudes are verified against the phantom's documented shifts and confirmed on AlignRT as the phantom is moved
 - The central isocenter is then selected in AlignRT and offsets are recorded (should be <1.0mm)
 - The Daily Imaging plan is then closed on the TrueBeam and AlignRT
 - A Daily MMI DICOM RT plan is then opened on the TrueBeam and AlignRT system is selected as the gating device on the TrueBeam
 - The MMI interface prompts the used to open the same patient in AlignRT
 - The MMI plan has a single field aligned to the original offset isocenter (original setup position)
 - The offset isocenter is selected in AlignRT which now defaults to the previously captured reference surface
 - The phantom (currently at the central isocenter) is monitored with the offset isocenter selected in AlignRT in order to obtain deltas
 - The Move Couch button then becomes active and the couch is shifted back to the original setup position using AlignRT and the MMI interface
 - Once the phantom is remotely repositioned and the tolerances are met for at least one monitoring frame the field is authorized for delivery on the TrueBeam.
 - Delivery is initialized on the TrueBeam.
 - During delivery a fake couch shift is selected in the AlignRT interface to mimic a patient motion outside the set tolerances which in turn should gate the delivery using the MMI initiated beam hold.
 - The gating is tested 3 times during delivery each time returning to the real couch position to allow the beam to complete delivery
 - Finally the therapists verify that the remote couch move returned the phantom to its original setup position by confirming the lasers on the exterior phantom marks/bbs.

The above procedure tests all recommended TG-147 items and does so on a daily basis without placing undue burden on the therapists. Monthly tests are completed in a similar manner by the physicists. Further systematic image based verification is currently being developed for statistical trending of system performance.



Setting up the Isocenter Cube for End-to-End Testing

- Purpose
 - To outline a simple procedure for generating an end-to-end test phantom using the Vision RT Isocenter Cube. This phantom can then be used to complete the following testing during both commissioning and for end-to-end checks prior to patient plan delivery.
 - TG-147 Tests
 - Static localization accuracy
 - Dynamic localization accuracy
 - Positioning accuracy
 - Gating and tracking capabilities
 - Camera Obstruction Test
 - TG-53 testing of TPS and TPS validation pre and post upgrades
 - You can also use this procedure to verify the etching on the phantom in relation to the central sphere.
- Procedure
 - Align the Vision RT Isocenter Cube on the CT table in order to acquire a 3D CT data set of the phantom.
 - Be sure to remove all rotations from the phantom using a high precision level.
 - Yaw rotations can be limited by using an index bar to straighten the phantom along the long axis of the couch
 - Align phantom to external CT lasers and zero system at that point
 - Take preliminary scans to verify phantom setup using CT measurement tools and image grid overlays
 - ***If using 4D CT for SRT patient simulation perform the following steps with and without***

induced motion during CT simulation being sure to complete a 4D CT using your chosen system during the motion scan.

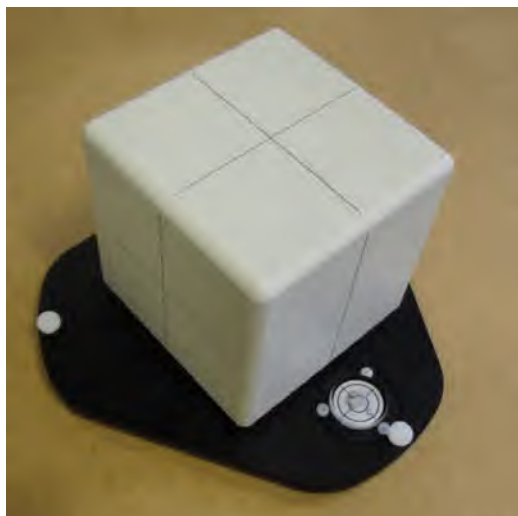
- Once phantom is aligned acquire 3D CT scan of the phantom using your SRS scan protocol
 - Protocol should have small slice thickness for small intracranial mets (e.g. 0.5, 0.625, 1.0, 1.25, or 1.5 depending on your CT vendor)
- Isocenter placement at the time of simulation is not critical for this phantom but if you wish to test this as well follow the steps below.
 - If you have a laser system that allows placing isocenter at the time of simulation...
 - Load the acquired CT into your vendor's virtual simulation software (data transfer may be required)
 - Place isocenter in the central sphere (refer to user manual for determination of sphere location)
 - Push laser localization from virtual simulation software to laser system (use vendor specific instructions)
 - Drive lasers to placed isocenter coordinate and verify laser position on phantom etching.
 - If lasers do not fall on etching you can try placing again or contact vendor if you feel etching is off
- Push CT (and DICOM RT plan if isocenter was placed) to the clinical treatment planning system (TPS)
- Import CT (and DICOM RT plan if applicable) into TPS
- Contour "Body" structure as the exterior surface of phantom and the 5 internal spheres.
 - Be sure to label spheres and use distinct contours so they are distinguishable at the machine when imaging and fusing.
 - Compute volume of "Body" structure and compare to computed value from spec sheet (cube with 150.00mm sides).
 - Measure dimensions edge-to-edge through the center of the phantom and multiply when comparing volumes
 - Don't use the TPS compute contour volume functions to account for the 8mm rounded edges on the phantom
 - Measure all three dimensions of the phantom to ensure accurate reconstruction of the phantom and that the faces of the phantom parallel to the CT plane were captured.
 - Measure volume of spheres and compare to computed values (5 x 7.5mm diameter spheres)
 - Measure sphere diameters and compare to documentation (7.5mm)
 - Measure center to center distance from sphere to sphere and verify against documentation
 - Distance from center of phantom (mm) for each sphere (verify against user's specific cube model)
 - Sphere 1 (-10.0, -25.0, -30.0)
 - Sphere 2 (10.0, -15.0, -15.0)
 - Sphere 3 (0.0, 0.0, 0.0)
 - Sphere 4 (-20.0, 20.0, 10.0)
 - Sphere 5 (20.0, 30.0, 20.0)
- Once phantom geometry has been verified place an isocenter at the center of each sphere.
- Finalize plans at each isocenter and push through your specific system (TPS-R&V-Machine) for localization and verification on the treatment couch.
 - Follow the same procedures as you would for a patient testing the data transfer integrity along the way in order to identify any data transfer errors or rounding issues from system to system.
 - Compare available metrics (contour volumes, distances, ...etc.) along the way to both the TPS values and documentation values for the phantom.
 - See **Varian Specific Note** below for Varian specific recommendations.

- Now you can schedule the phantom patient for imaging and Winston-Lutz verification (see **Winston-Lutz** slide for procedure) at each of the 5 sphere locations.

Varian Specific Note

If you are using Eclipse and have a Varian C3 or TrueBeam machine with File mode capabilities you can create a Winston-Lutz plan using a minimum of 8 beams at 8 distinct gantry/couch/collimator positions at one sphere location and then easily copy this plan to the other isocenters (center of the other spheres) for hidden target validation via automated WL tests. You can also create the test using MLCs, Jaws, and Cones to make these test much quicker and easier to reproduce during commissioning and at the time of your annual testing. Once completed you can export the DICM RT plan to the machine and AlignRT for all future testing.

The user can also include MV and kV fields for the isocenter cube calibration at the central sphere isocenter and use this same plan to perform you isocenter cube calibration and imaging verification for SRS.



0° Position



45° Position

Figure 2.6 SRS QA Phantom Positions on Levelling Plate

2.3 Cube Orientation

The cube can only be orientated one way with respect to its base plate by the way the plinth of the cube, interlocks with the base plate. This interlock is formed by a cut away on one corner of the plinth.

The 'front' face of the cube is then defined as the face with the cut-away at the bottom left corner.

For normal use the cube and levelling plate will be placed on the couch such that the front face is facing away from the gantry and the body of the treatment delivery system

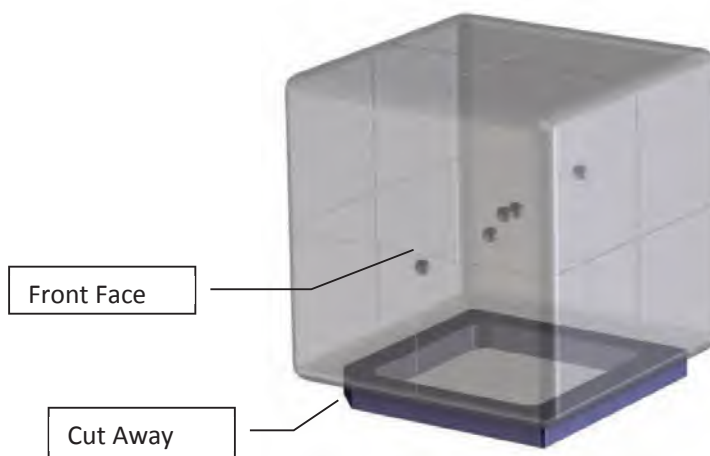


Figure 2.7 Cube Orientation

2.4 Cube Coordinate System

Not only does the cut away on one corner of the plinth on the base of the cube define the cube orientation, it also defines the position of the origin of the cube, as it allows one corner of the cube to be unambiguously identified.

Assuming that the cube is correctly orientated with respect to the patient couch coordinate system then the cube coordinate system then it follows that:

- Z – Vertical axis, with the positive direction being towards the top;
- X – Transverse axis (left to right), with the positive direction being to the right; and
- Y – Longitudinal (front to back), with the positive direction being towards the back.

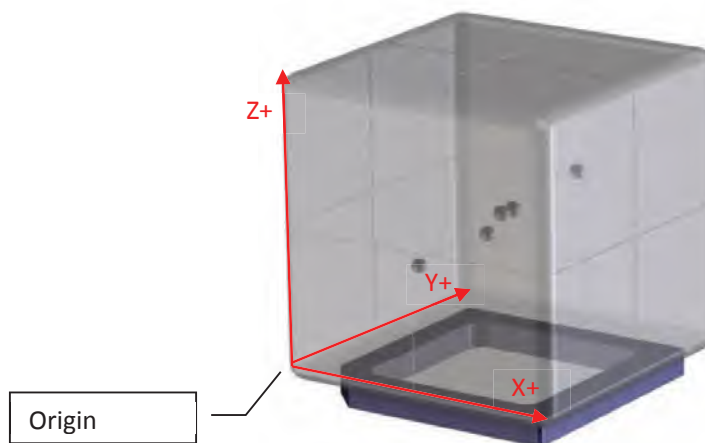


Figure 2.8 Cube Coordinate System

2.5 Sphere Locations

The cube contains 5 ceramic spheres with a nominal diameter of 7.50mm. One of these spheres is located in the middle of the cube and the other four are arranged asymmetrically about this centre sphere. The arrangement of the four peripheral spheres is such that the orientation of the cube with respect to radiographic images (or the orientation of the radiographic images with respect to the cube) can be easily determined and verified.

For convenience, the spheres are numbered sequentially, based on their proximity to the origin of the cube. Thus the spheres are numbered from the bottom to top and from front to back (see Figures 2.9 and 2.10).

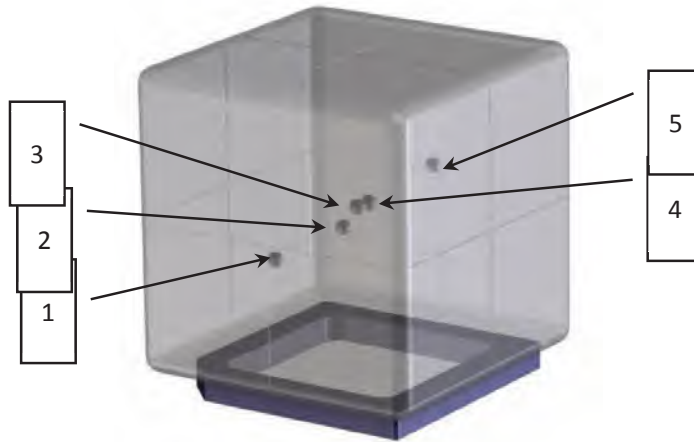


Figure 2.9 Sphere Numbering

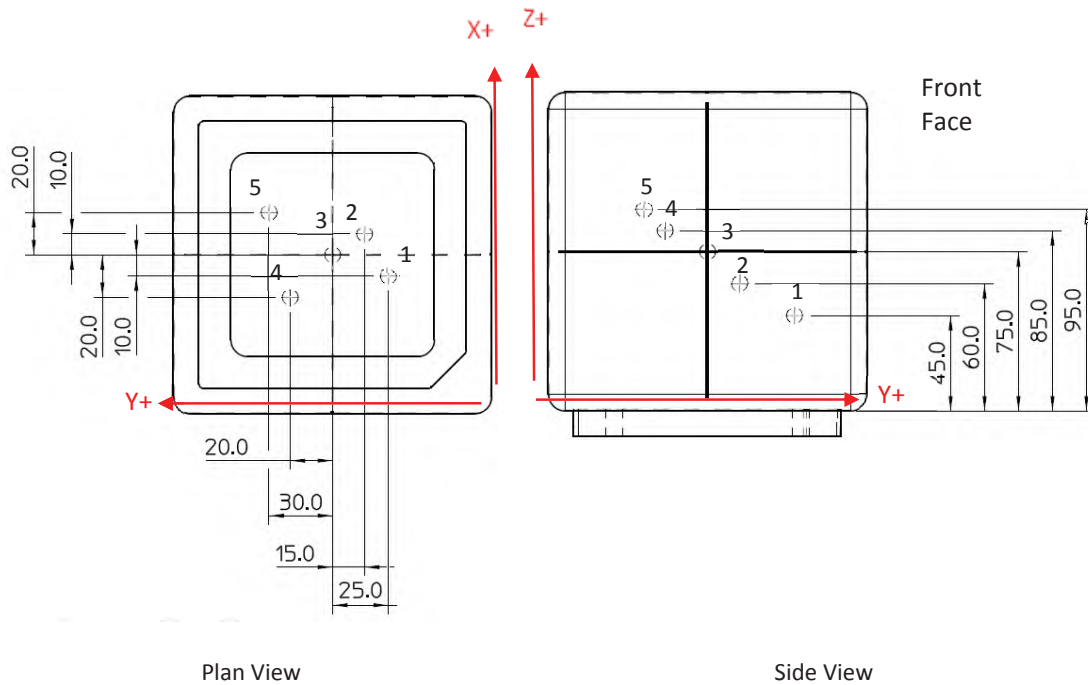


Figure 2.10 Sphere Positions

Table 2.1 Sphere Positions with respect to the Centre of the Phantom

Sphere	X	Y	Z
1	-10.00	-25.00	-30.00
2	+10.00	-15.00	-15.00
3	0.00	0.00	0.00
4	-20.00	+20.00	+10.00
5	+20.00	+30.00	+20.00

Table 2.2 Sphere Positions with respect to the Origin of the Phantom

Sphere	X	Y	Z
1	65.00	25.00	45.00
2	85.00	60.00	60.00
3	75.00	75.00	75.00
4	55.00	95.00	85.00
5	95.00	105.00	95.00



Winston-Lutz using portal imaging system

- Purpose
 - To outline a simple procedure for completing a Winston-Lutz test using the portal imaging system.
- Procedure
 - Ensure proper calibration and maintenance has been performed on all machine components and that they meet TG-142 recommendations for SRS prior to running a Winston-Lutz test.
 - Align phantom with radio-opaque target to isocenter using positioning system you wish to test.
 - Take a minimum of 8 images at 8 distinct gantry/couch/collimator positions
 - If you routinely lock out the collimator (often done for cone based treatments on machines with vendor supplied SRS interlocks) only gantry and couch combinations are required.
 - Talk to you machine vendor for options in automating this process
 - Automation reduces variability from test to test making statistical trending of data more reliable in the future
 - See **Varian Specific Note** below
 - Process images using commercially available software such as DoseLab Pro, PipsPro, MachineQA, or QA Pilot to determine the 3D offset of the target in relation to the field center.
 - If you have your own home grown solution or program for analyzing these images be sure to benchmark and document against another system for validation of the results before use in clinical commissioning or patient treatment quality assurance.
 - Document 3D offset of target relative to the zero position of the alignment system being tested for trending later.
 - **(Recommendation)** Statistical trending of results by means of a run chart or some

other method (e.g. statistical t test) can give you warning of system drift far faster and with a higher degree of sensitivity than basic thresholds.

(Varian Specific Note)

Automation can be accomplished on a Varian C3 or TrueBeam machine by generating a DICOM RT plan with the desired gantry/couch/collimator combinations in Eclipse for use in File mode at the machine.

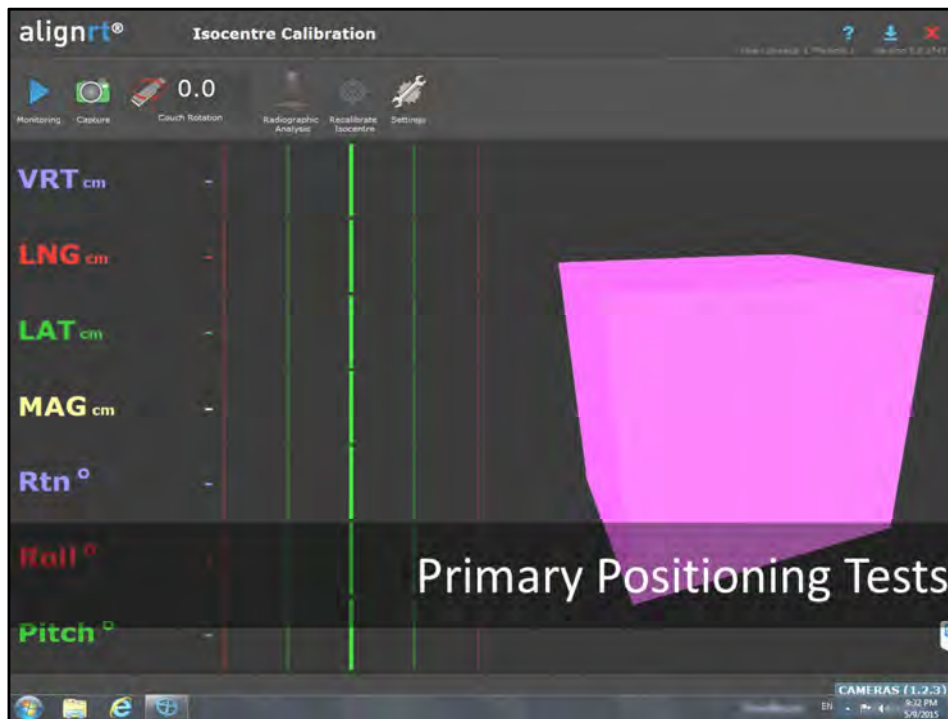
- Ensures a reproducible set of gantry/couch/collimator combinations for statistical trending of data over many tests.
- Allows for fast acquisition of images and easy accessibility to the images post imaging session.
- Reduces variability in testing procedure and effects due to image quality settings from physicist to physicist and test to test.
- If you have a Varian Machine but a different planning system a plan from another institution can be used as long as the plan is compatible with your machine and you have the rights to machine override at the time of delivery.



Couch walkout determination using AlignRT and Isocenter Cube

- Purpose
 - To determine the mechanical stability of the treatment couch for non-coplanar treatments where multiple table angles are routinely used to accomplish a treatment at one or more isocenters
- Procedure
 - Make sure your AlignRT Monthly calibration procedure has been completed (Use vendor recommended procedure)
 - Perform Isocenter Cube calibration (Use vendor recommended procedure)
 - Validate calibration using secondary procedure (e.g. Winston-Lutz and central sphere location)
 - Align the Isocenter Cube to Isocenter from within the **Isocenter Calibration** screen using the ideal geometry for the cube as a reference
 - With all offsets dialed out to zero with couch at zero (home) position (Couch angle 0 in IEC 1217 coordinate system)
 - Validate rotational tracking by rotating the couch to 270 and 90 and check the corresponding angular offset reported by the machine, AlignRT, and reference indicator (e.g. lasers on phantom etching)
 - If rotational accuracy is acceptable return couch to home position ensuring any offsets return to zero at the home positions
 - Rotate the couch to max extent in both counter clockwise and clockwise directions using a predefined angular offset (e.g. every 10, 15, or 20 degrees)

- Repeat above step as many times as you like to ensure good sampling at each couch angle.
 - Upon each cycle validate offsets at home position to validate couch mechanical stability
- Use data to plot couch walkout vs couch angle



Positioning Tests for AlignRT

Test assume you have setup the Isocenter Cube as an end-to-end phantom using the procedure outline in the *Isocenter Cube for End-to-End Testing* slide

Initial Setup Procedure

- Using the Isocenter Cube use the Isocenter Calibration portion of the AlignRT software to align the phantom to isocenter.
- Verify the phantom positioning using the Radiographic Analysis feature or using a standard Winston-Lutz on the central sphere
 - If the Radiographic Analysis or the Winston-Lutz reveals a calibration issue recalibrate the isocenter.
- Once you have confirmed alignment with the center of the phantom and the central sphere you are ready to start testing.

Static repositioning accuracy (using only AlignRT)

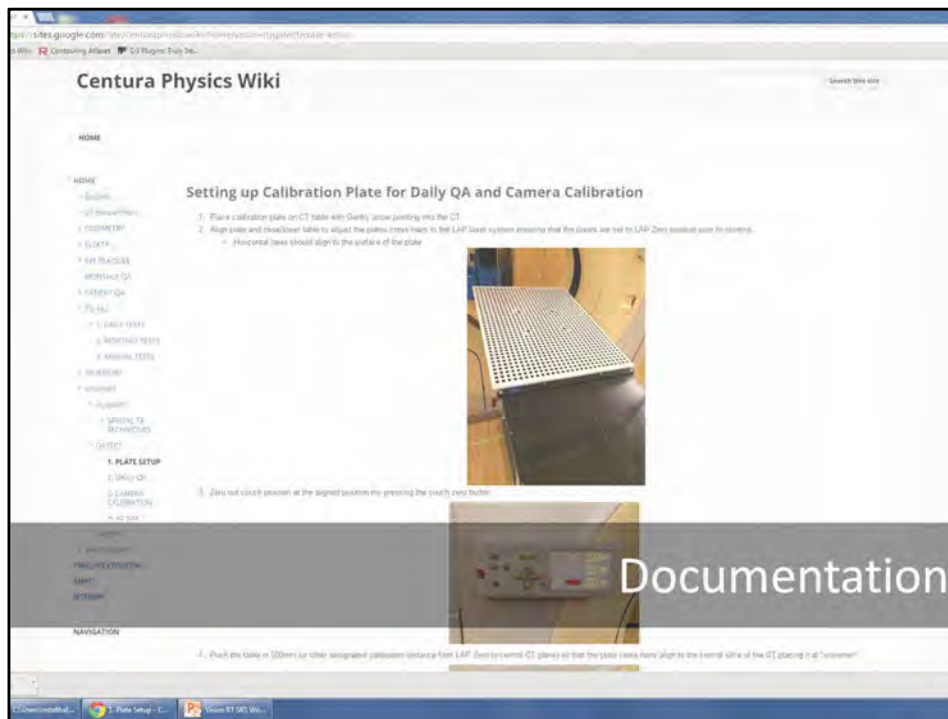
- Once you have confirmed alignment with the center of the phantom and the central sphere shift to one of the other sphere locations using only the AlignRT readouts and the phantom documentation for distance reference.
- Perform Winston-Lutz at the new position and note 3D positional offset of the target
- Using you imaging system (planar imaging or CBCT) image the phantom using the DICOM RT plan outlined in the

Dynamic position tracking and accuracy

- Once you have confirmed alignment with the center of the phantom and the central sphere shift to one of the other sphere locations using the DICOM RT plan outlined in the *Isocenter Cube for End-to-End Testing* slide above using the linac imaging system (be sure to be monitoring the Isocenter Cube).
- Upon shifting note the imaging system shifts and the shifts recorded by AlignRT
- Perform Winston-Lutz at the new position and note 3D positional offset of the target

Position Readout with Obstruction Test

- Once you have confirmed alignment with the center of the phantom and the central sphere rotate the gantry or extend imaging arms to obstruct the camera views and note function of the system.
 - Note any position readout changes



Documentation of your Procedures

When you have finally completed testing and have run through your end-to-end testing you should document all of your procedures and make the easily accessible to the staff.

Things to document

- Vendor training and those that attended
- Acceptance testing of the installed system (both vendor and site specific tests TG-147...etc.)
- Commissioning reports listing all the testing that was completed and the results of those test
 - Should include a release for clinical use
- Daily, Monthly, and Annual tests and testing procedures
 - Can include checklists and/or step-by-step instructions
 - If you create standardized test plans they should be identifiable in you TPS and on you delivery system
 - There should be some type of identification as to who should perform the tests and at what frequency
- Calibration procedures
- Software / Hardware Upgrade and repair testing requirements for clinical release

A close-up, black and white photograph of a human eye with a striking yellow iris. The eye is looking slightly to the right. The eyelashes are dark and well-defined. A semi-transparent dark grey horizontal bar is overlaid across the middle of the eye, containing the text "Questions?".

Questions?

Vision RT – Users Meeting 2015
(User Workshop on SRS)
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