Selection of Key Documents and resources related to Treatment Planning System Commissioning and Quality Assurance

Year	Who	Nature of document	Title	Comments
1955	Tsien, K. C.	Br. J. Radiol. 28, 432–439 (1955)	The Application of Automatic Computing Machines to Radiation Treatment Planning.	• First use of computers for treatment planning
1980	McCullough et al.	Int. J. Radiat. Oncol. Biol. Phys. 6, 1599 - 1605 (1980)	Performance Evaluation of Computerized Treatment Planning Systems for Radiotherapy: External Photon Beams	• 1st general article on TPS QA • list of recommended tests • Discussion of appropriate accuracy
1987	ICRU	ICRU Report 42	Use of computers in External beam Radiotherapy Procedures with High-Energy Photons and Electrons	• Very General Recommendations: • Repeat same calculation on a regular basis • Maintain manual calculation skills • In Vivo measurements in limited cases
1990	Jacky et al.	Int. J. Radiat. Oncol. Biol. Phys. 18, 253 – 261 (1990)	Testing a 3-D Radiation Therapy Planning Program	• Compare against independent calculations • Testing based on program specifications • Performed hand calculations to match computer generated output using the same algorithm as computer
1993	Van Dyke et al.	Int. J. Radiat. Oncol. Biol. Phys. 26, 261–273 (1993)	Commissioning and Quality Assurance of Treatment Planning Computers	• Comprehensive overview of TPS Commissioning and QA • Detailed tests for both commissioning and ongoing QA described • Recommended tolerances given • Recommends both manual point dose calculation check and in Vivo dosimetry
1997	Swiss Society of Radiobiology and Medical Physics Born et al.	SSRPM Recommendations 7 (1997) http://www.ssrpm.ch/old/r07tps-e.pdf	Quality Control of Treatment Planning Systems for Teletherapy Recommendations No 7	• Very practical guidelines

Year	Who	Nature of document	Title	Comments
1998	AAPM Fraass et al.	Med. Phys. 25 1773-1829 (1998) TG #53	Quality assurance for clinical radiotherapy treatment planning	• Covers acceptance, commissioning, ongoing QA, Personnel • Incudes tests of imaging, dose calculation, output, security • For Photon, Electron, Brachytherapy
2001	ICRP	Publication 86 Ann. ICRP 30, 1–70 (2001)	Prevention of accidental exposures to patients undergoing radiation therapy	• Summary and analysis of accidents in RT
2002	Kilby W. et al	Phys. Med. Biol. 47 1485–1492 (2002)	Tolerance levels for quality assurance of electron density values generated from CT in radiotherapy treatment planning.	• An 8% error in estimating tissue density will cause a 1% dose error
2003	AAPM Ezzell et al.	Med. Phys. 30, 2089–2115 (2003)	Guidance document on delivery, treatment planning, and clinical implementation of IMRT	• 1st Guidance document on IMRT • Inverse planning • Leaf sequencing algorithms • MLC leaf gap • Modeling small fields • Discusses individual patient QA
2003	AAPM Mutic et al.	Med. Phys. 30, 2762-2792 (2003) TG #66	Quality assurance for computed-tomography simulators and the computed tomography-simulation process	• Includes RED curve tests and DRR tests
2004	AAPM Papanikolaou et al.	TG #65	Tissue Inhomogeneity Corrections for Megavoltage Photon Beams	• Highlights increased complexity of TPS calculations with CT based planning
2004	ESTRO Mijnheer et al.	Booklet #7 http://www.estro.org/school/articles/publications/publications	Quality Assurance of Treatment Planning Systems Practical Examples for Non-IMRT Photon Beams	• Include block cutter and Data Transfer checks
2004	IAEA	Technical Report #430 http://www-pub.iaea.org/mtcd/publications/pdf/trs430_web.pdf	Commissioning and Quality Assurance of Computerized Planning Systems for Radiation Treatment of Cancer	• Includes purchase process, training, patient specific QA, recommendations after upgrades • 244 recommended tests • Emphasis on staffing and reporting structures

Year	Who	Nature of document	Title	Comments
2005	Netherlands Commission on Radiation Dosimetry Buinvis et al.	NCS Report 15 (2005). http://radiationdosimetry.org/files/documents/0000016/69-ncs-rapport-15-qa-3-d-tps-external-photon-and-electron-beams.pdf	Quality assurance of 3-D treatment planning systems for external photon and electron beams	
2006	AAPM Keall et al.	Med. Phys. 33 3874-3900 (2006) TG #76	The management of respiratory motion in radiation oncology	
2007	IAEA	TECDOC 1540 http://www-pub.iaea.org/MTCD/publications/PDF/te_1540_web.pdf	Specification and Acceptance Testing of Radiotherapy Treatment Planning Systems	• Provides Data, Tests and Results for use in evaluating a TPS • Include functional tests, dose accuracy tests, • This IAEA report uses the description of the tests directly from the IEC 62083 Standard
2007	AAPM Chetty et al.	AAPM Med. Phys. 34 4818-4853 (2007) TG #105	Issues associated with clinical implementation of Monte Carlo-based photon and electron external beam treatment planning	• Issues specific to Monte Carlo algorithms
2008	IAEA	IAEA TECDOC 1583 http://www-pub.iaea.org/MTCD/publications/PDF/te_1583_web.pdf	Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques	• Practical tests relevant to typical planning scenarios • Helps give a sense of accuracies in planning system
2008	ESTRO Alber et al.	Booklet #9 http://www.estro.org/school/articles/publications/publications	Guidelines for the Verification of IMRT	• Includes In Vivo dosimetry • Summarizes practices at different centers
2008	AAPM Das et al.	Med. Phys. 35, 4186–4215 (2008) TG #106	Accelerator beam data commissioning equipment and procedures	• Include recommendations for pre-processing data prior to use with TPS commissioning
2008	Breen S, et al	Med. Phys. 35, 4417–4425 (2008)	Statistical process control for IMRT dosimetric verification	• Process Control charts applied to IMRT QA

Year	Who	Nature of document	Title	Comments
2009	AAPM Ezzell et al.	Med. Phys. 36, 5359 - 5373 (2009). TG #119	IMRT commissioning: Multiple institution planning and dosimetry comparisons	• Clinically relevant set of tests • Reports plan results and measurements from 10 different institutions • Planning and QA test data available via aapm.org
2009	AAPM Siochi et al.	JACMP 10(4) 16-35 (2009) TG #201 Initial Report	Information technology resource management in radiation oncology	• Tasks and personnel required for radiation oncology IT infrastructure
2009	ICRP	Publication112 Annals of the ICRP 39 (2009).	Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies.	• An expansion of ICRP 86 focusing on the risks in new technology
2011	Nelms et al	Med. Phys. 38, 1037–1044 (2011).	Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors.	• A critical evaluation of IMRTQA techniques
2012	ACR Hartford et al.	Am. J. Clin. Oncol. 35 612-617 (2012)	Practice Guideline for Intensity-Modulated Radiation Therapy (IMRT)	• High level document
2012	Ford et. al.	Int. J. Radiat. Oncol. Biol. Phys. 84 263-269 (2012)	Quality Control Quantification (QCQ): A tool to measure the value of quality control checks in radiation oncology	• Critical analysis of the effectiveness of various QA techniques
2012	Li et al.	Med. Phys. 39 1386-1409 (2012)	The Use and QA of Biologically Related Models for Treatment Planning	•
2013	Molineu et al	Med. Phys. 40 022101 2013	Credentialing results from IMRT irradiations of an anthropomorphic head and neck phantom	• Significant number of failures with RPC Credentialing
2013	IAEA	Training Course https://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/AccidentPreventionRadiotherapy.htm	Prevention of Accidental Exposure in Radiotherapy	• Review and analysis of select incidents in Radiation Therapy • Includes some related to treatment planning system
2014	AAPM Gibbons et al.	Med. Phys. 41, 031501 (2014). TG #71	Monitor unit calculations for external photon and electron beams	Includes discussion of manual vs TPS MU calculations

Year	Who	Nature of document	Title	Comments
2014	AAPM Olch et al.	Med. Phys. 41, 061501 (2014) TG #176	Dosimetric effects caused by couch tops and immobilization devices: Report of AAPM Task Group 176	
2014	Mcvicker, A. T., et al.	Master's Thesis from Duke University http://dukespace.lib.duke.edu/dspace/handle/10161/8859	Clinical Implications of AAA Commissioning Errors and Ability of Common Commissioning & Credentialing Procedures to Detect Them.	• Deliberately introduced errors into TPS parameters to determine dosimetric effect • Applied TG #119 and IROC TLD tests to evaluate their effectiveness at detecting the errors
2014	Noel et al	Int J Radiation Oncol Biol Phys. 88 1161-1166 (2014)	Quality assurance with plan veto: Reincarnation of a record and verify system and its potential value	• A tool to check RT data transfer
2015	CPQR Villarreal et al.	CPQR Radiotherapy Guidance Document http://www.cpqr.ca/programs/technical-quality-control/	Technical Quality Control Guidelines for Canadian Radiation Treatment Centres: Treatment Planning Systems	• Some things not covered by other documents e.g.: • Backup restore test, • Checking error logs, • Detailed end-to end test, • Review by second medical physicist
2015	AAPM	JACMP 16(5) 14-34 (2009) MPPG #5	Treatment Planning System Commissioning and QC/QA	
2016	CPQR Pomerleau-Dalcourt et al.	CPQR Radiotherapy Guidance Document http://www.cpqr.ca/programs/technical-quality-control/	Technical Quality Control Guidelines for Canadian Radiation Treatment Centres: Data Management Systems	• Data transfer integrity • System recovery tests e.g. power failure • Data quality checks: Can the system recognize corrupted data?
2016	AAPM Huq et al.	Med. Phys. 43, 4209–4262 (2016) TG #100	Application of risk analysis methods to radiation therapy quality management	

Anticipated Documents

Who	Nature of document	Title
AAPM	TG #132	Use of Image Registration and Data Fusion Algorithms and Techniques in Radiotherapy Treatment Planning
AAPM	TG #157	Commissioning of beam models in Monte Carlo-based clinical treatment planning
AAPM	TG #201	Quality Assurance of External Beam Treatment Data Transfer
AAPM	TG #218	Tolerance Levels and Methodologies for IMRT Verification QA
AAPM	TG #219	Independent Dose and MU Verification for IMRT Patient Specific Quality Assurance
AAPM	TG #262	Electronic Charting
AAPM	TG #275	Strategies for Effective Physics Plan and Chart Review in Radiation Therapy

Incident Learning Systems:

ASTRO Radiation Oncology –Incident Learning System (RO-ILS)
North American
https://www.astro.org/roils/

Safety Reporting and Learning System for Radiotherapy (Safron)
Operated by IAEA
https://rpop.iaea.org/RPOP/RPoP/Modules/login/safron-register.htm

Radiation Oncology Safety Information System (ROSIS)
Operated by ESTRO
http://www.rosis.info/index.php

Control Chart Resources

American Society for Quality

- Provide some good resources and templates for control charts and other quality tools

http://asq.org/learn-about-quality/data-collection-analysis-tools/overview/control-chart.html

National Institute of Standards and Technology

- Provide an Engineering Statistics handbook with many usefule guides and equations for data acquisition assessment and analysis.

http://www.itl.nist.gov/div898/handbook/index.htm

MoreSteam.com

- A for-profit organization providing training on process improvement
- A number of free on-line tutorials are available

https://www.moresteam.com/toolbox/index.cfm

Journal Articles by Todd Pawlicki

- A medical physicist who has been championing the use of control charts for more than 8 years
    - Pawlicki, T. *et al.* Moving from IMRT QA measurements toward independent computer calculations using control charts. *Radiother. Oncol.* **89,** 330–337 (2008).
    - Pawlicki, T. & Whitaker, M. Variation and Control of Process Behavior. *Int. J. Radiat. Oncol. Biol. Phys.* **71,** S210–S214 (2008).
    - Pawlicki, T., Whitaker, M. & Boyer, A. L. Statistical process control for radiotherapy quality assurance. *Med. Phys.* **32,** 2777–2786 (2005).
    - Pawlicki, T. *et al.* Process control analysis of IMRT QA: implications for clinical trials. *Phys. Med. Biol.* **53,** 5193–5205 (2008).

Other Resources

ECRI Institute

- Neutral third party organization providing
    - *Device alerts*
    - *Technology assessment*
    - *Consulting services*

https://www.ecri.org/about/Pages/default.aspx

i.treatsafely

Practical learning for RT professionals
https://i.treatsafely.org/

IHE-RO

Data transfer and interoperability issues in radiation oncology
https://www.astro.org/IHE-RO.aspx

OncoPeer

List service hosted by Varian Medical Systems
https://varian.force.com/OCSUGC

Treatment Planning System Commissioning and QA

Planning and Monitoring

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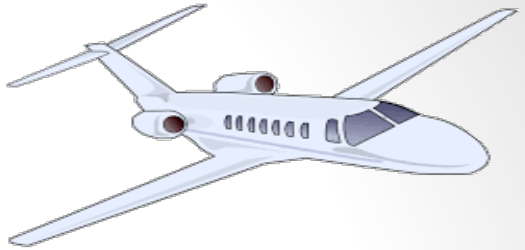
Outline



- **Documents and resources**
  - Good documents and resources are available
- **A knowledge-based approach to selecting and commissioning a planning system**
  - Focus on what you need to know.
- **Using control charts to enhance QA practices**
  - Control charts are useful when used correctly

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Early Documents

- **TG #53**
  - Covers acceptance, commissioning, ongoing QA, Personnel, security
- **IAEA Technical Report #430**
  - Very comprehensive
  - Emphasis on staffing and reporting structure
- **These documents are still useful**

Recent Documents

- **MPPG #5**
  - Most recent AAPM guidance on TPS
  - Does not replace early documents
- **IAEA TECDOC 1583**
  - Practical tests relevant to typical planning scenarios
- **CPQR Guidance Document on Treatment Planning Systems**
  - Higher level recommendations
  - Different perspective

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Specialty Documents

- **AAPM IMRT Guidance Document**
  - Inverse planning
  - MLC leaf gap
- **TG #105**
  - Issues specific to Monte Carlo algorithms
- **CPQR Guidance Document on Data Management Systems**
  - Data transfer integrity
  - System recovery tests
  - Data quality checks

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Incident Learning Systems

- **Benefits of a broad based Incident Learning System:**
  - Track and review internal incidents
  - Receive Reports on incidents/events from a larger community
  - Analyze and evaluate safety improvement efforts
  - Access to safety related articles and teaching
  - Promoting safety culture

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**“To err is human. To forgive is divine,
but to repeat is stupid.”**

Jaime Cardinal Sin, Catholic Archbishop of Manila

Available Incident Learning Systems

All of These are Free to Join

- ASTRO Radiation Oncology –Incident Learning System (RO-ILS)
  - *North American*
- Safety Reporting and Learning System for Radiotherapy (Safron)
  - *Operated by IAEA*
- Radiation Oncology Safety Information System (ROSIS)
  - *Operated by ESTRO*

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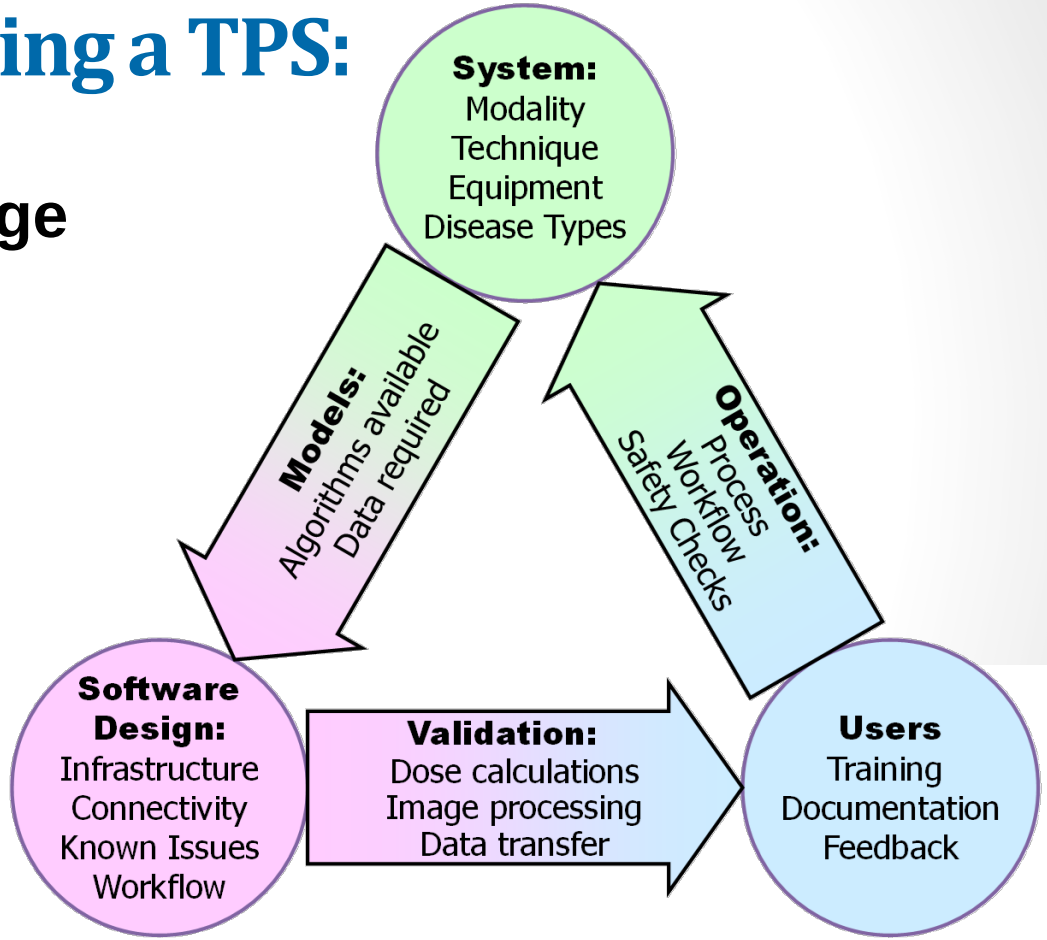
A knowledge-based approach to selecting and commissioning a TPS:

Acquired Knowledge

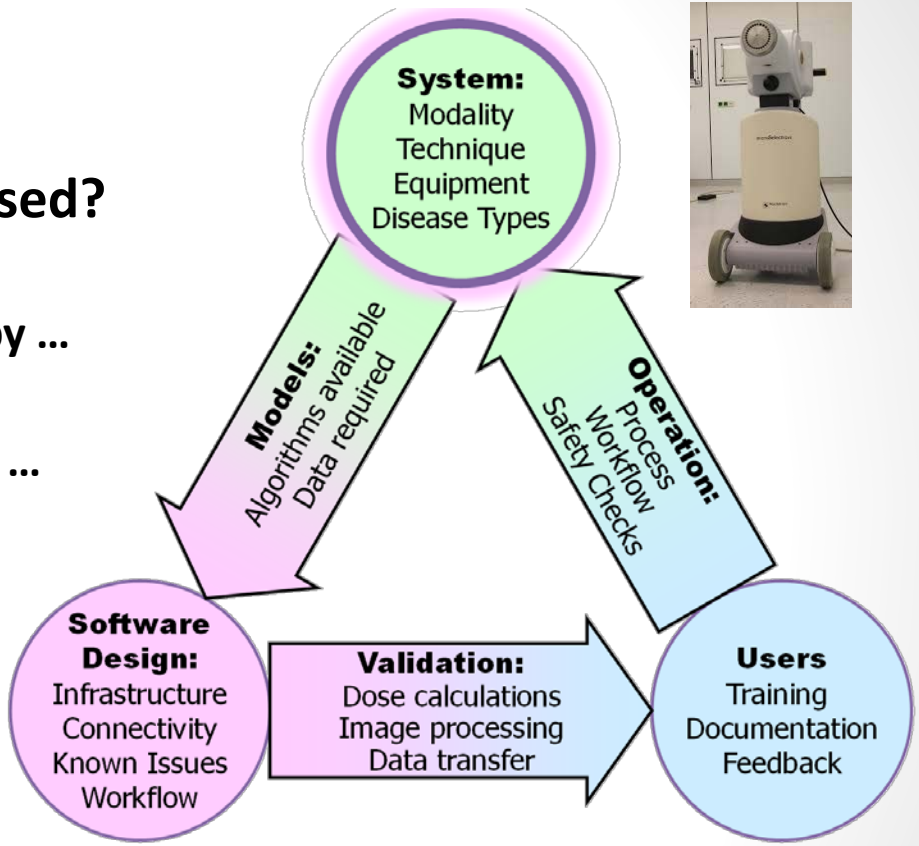
Required Action

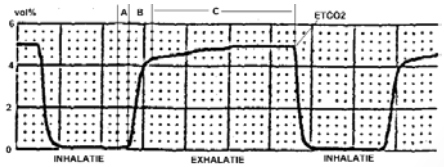


Kelly, D. Software Development Viewed as Knowledge Acquisition: Towards Understanding the Development of Scientific Software. *J. Syst. Softw.* **109,** 50–61 (2015).

RT System:

- **How is the planning system used?**
  - **Modality**
    - **External Beam, Brachytherapy …**
  - **Technique**
    - **3D Conformal, Gating, VMAT …**
  - **Equipment**
    - **Linacs, Imaging, R&V, HIS**
  - **Number of cases and case mix**





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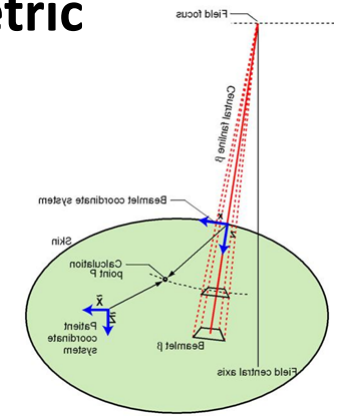
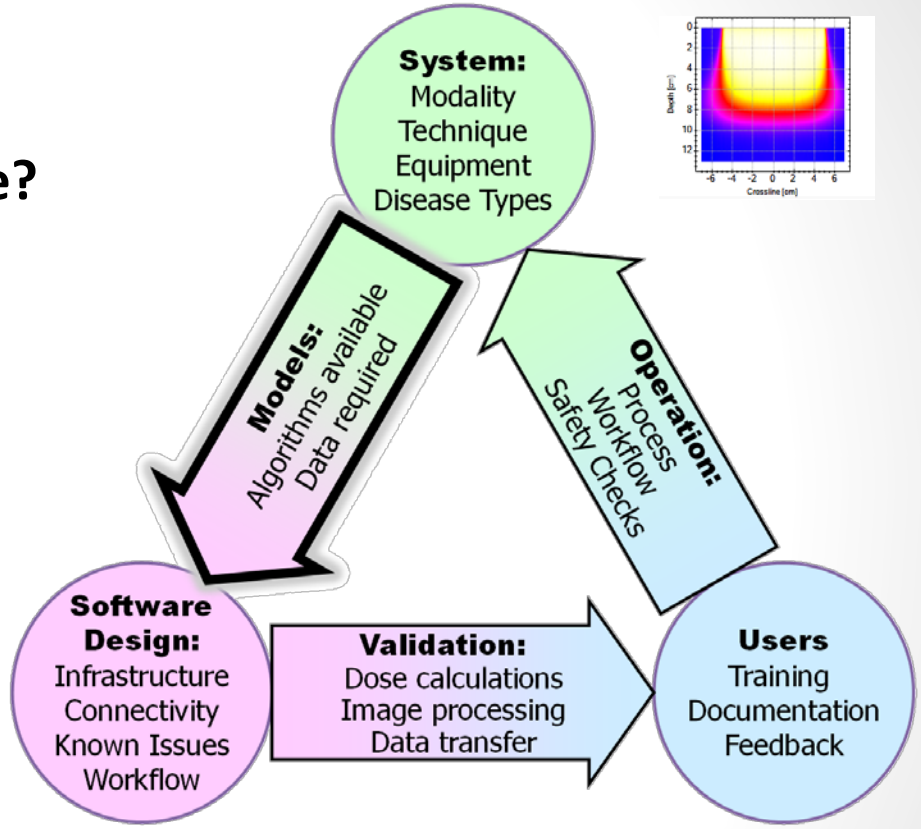
Models:

- **What algorithms are available?**
  - **What are their strengths and weaknesses?**
- **What data is required**
  - **Measurements**
  - **Non-dosimetric information**





$$k_z(z) = \frac{\rho(z)}{\rho_{\text{water}}} \sum_{i=1}^{2} c_i \frac{1}{\mu_i} e^{-\mu_i z'}$$

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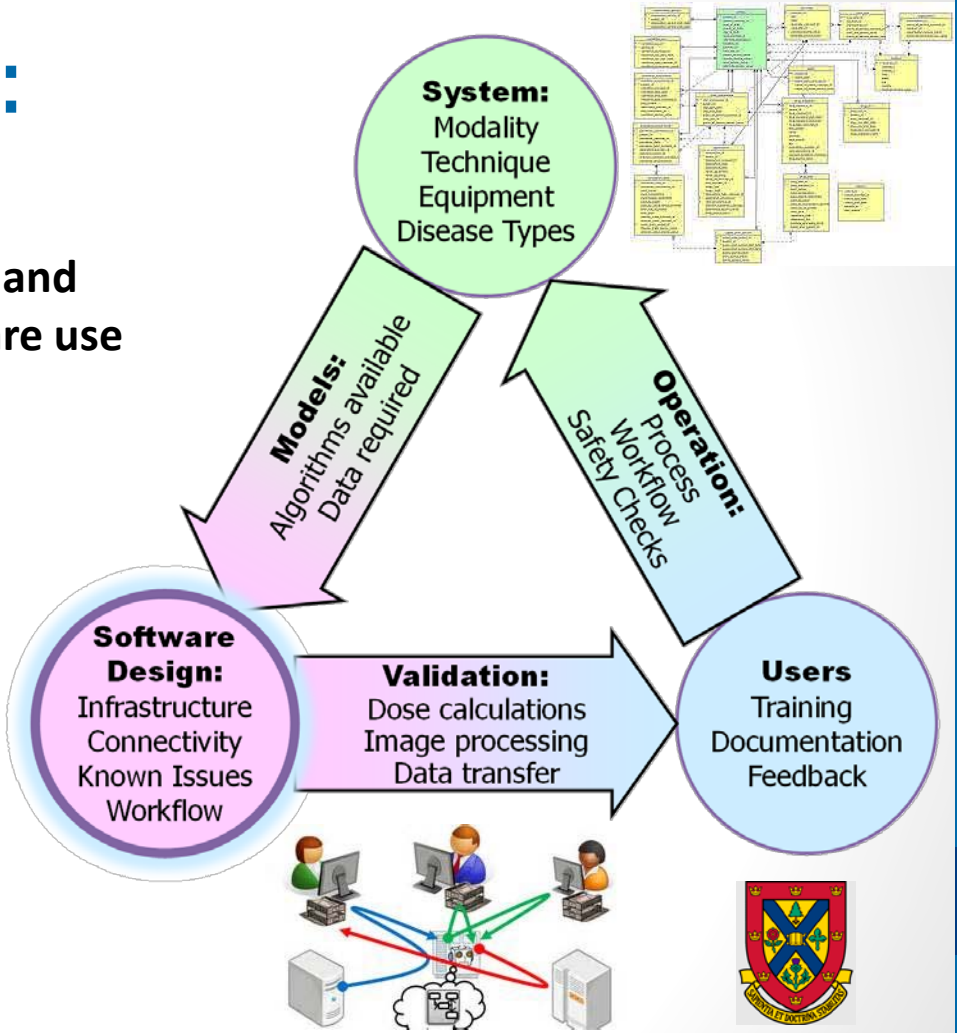
Software Design:

- **Intended workflow**
  - **Conflicts between intended and actual processes and software use**
- **Connectivity and Security**
  - ***Record & Verify***
  - ***Imaging***
  - ***Healthcare Data***
- **Hardware requirements**
  - **Backup and redundancy**



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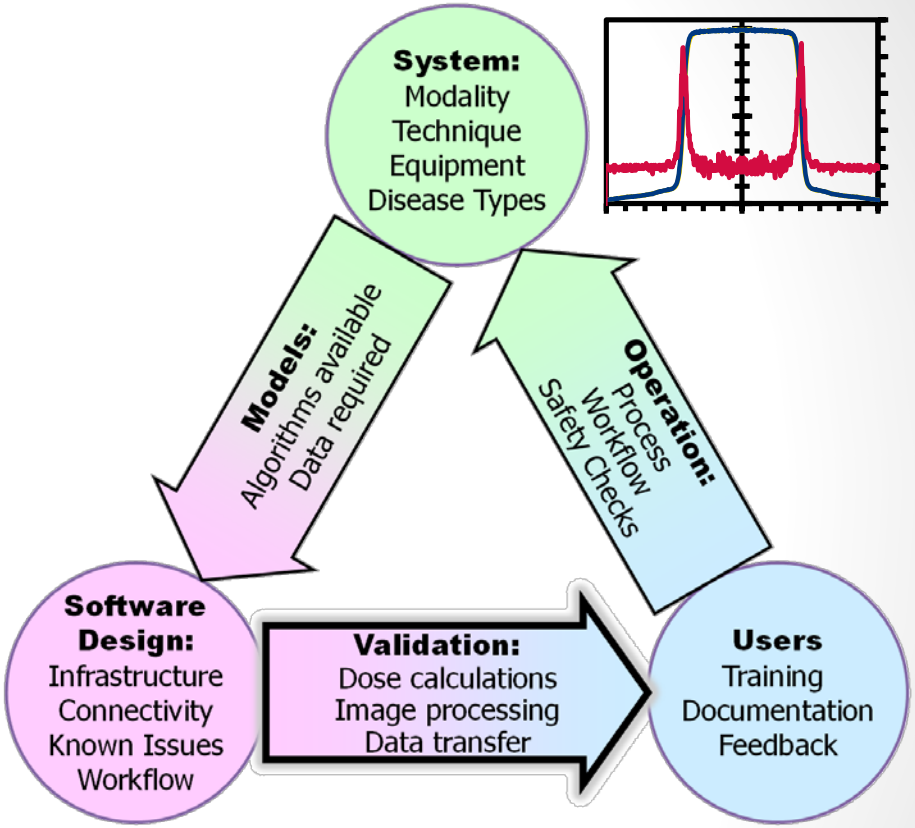
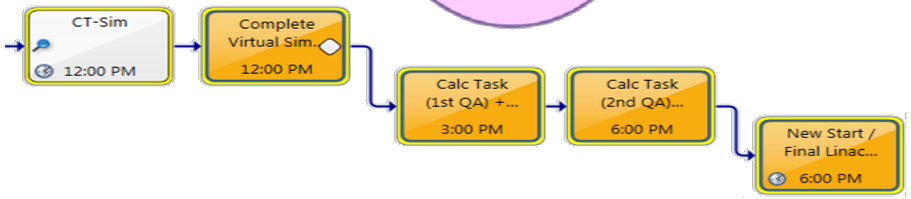
Validation:

- **Traditional "commissioning"**
  - **Data entry and validation**
  - **Non-dosimetric data configuration**
- **Connectivity testing**
- **Workflow testing**
- **Ongoing QA setup**





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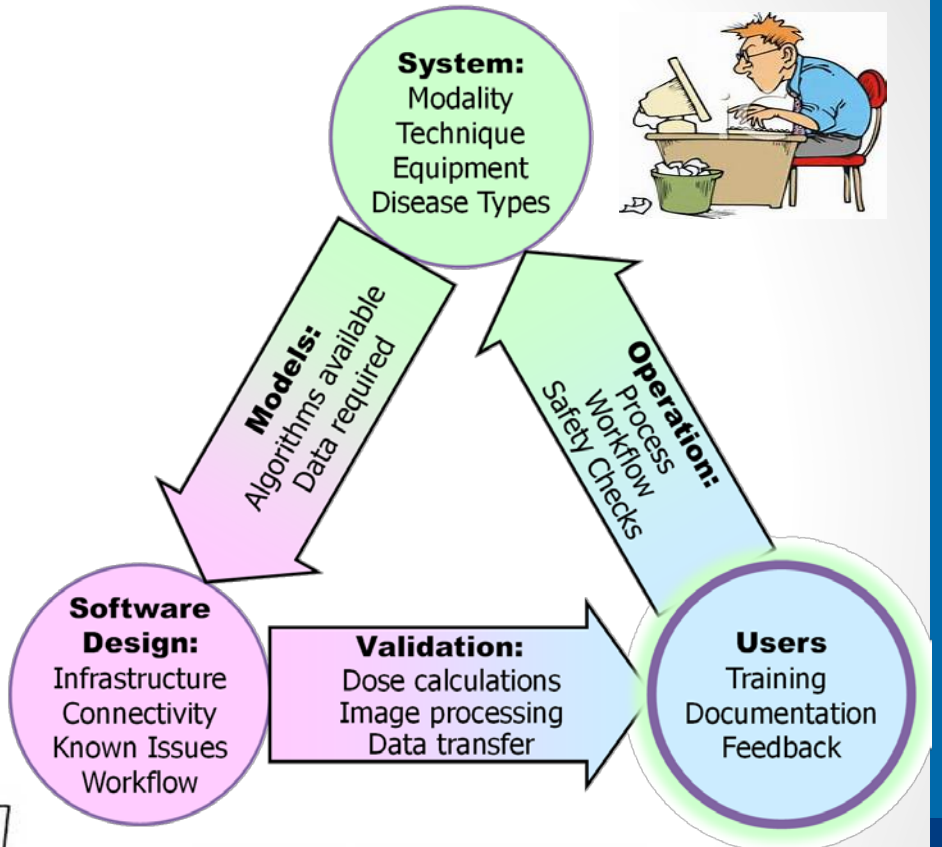
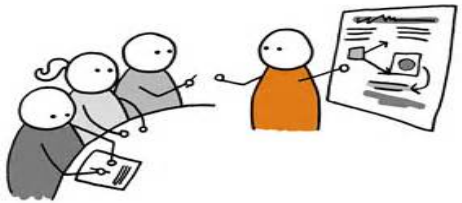
Users:

- **User groups**
  - Tasks & rights
- **Training & documentation**
- **Resources**
  - Quick references
  - Help desk
- **Environment**
  - Monitor size & resolution
- **Feedback process**





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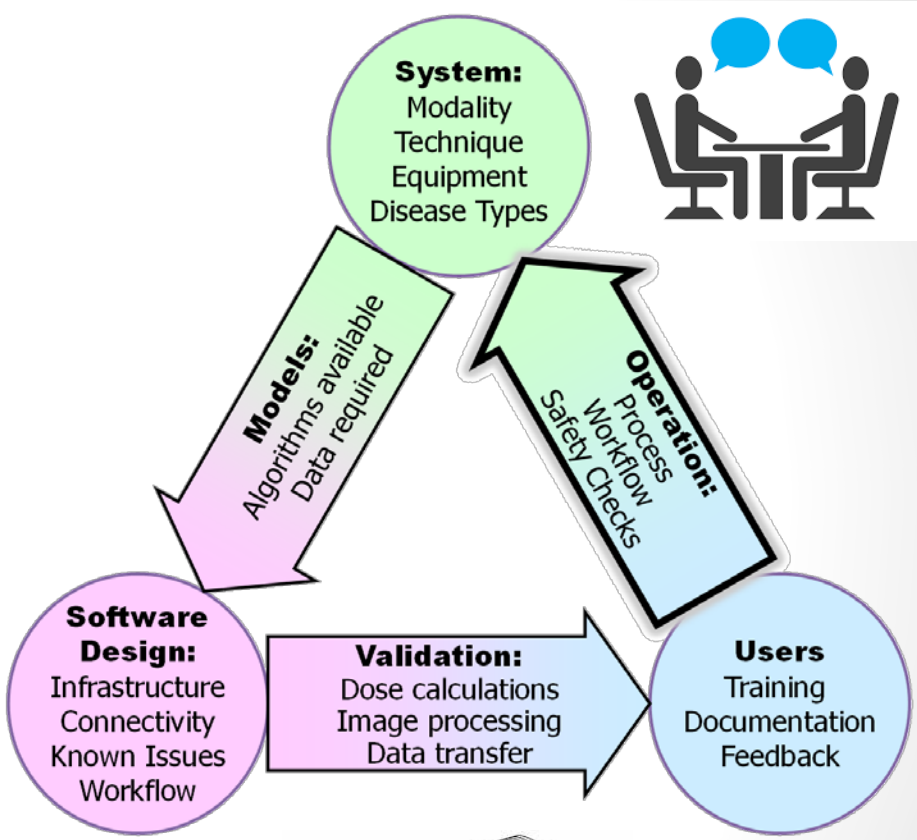
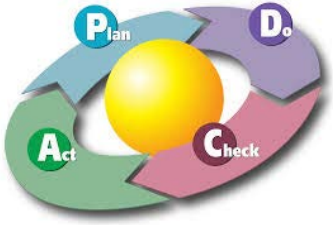
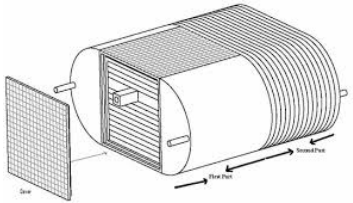
Operation:

- **Process review**
  - **Revise documentation**
  - **Incident learning**
- **Dosimetric Checks**
  - **End-to-end tests**
  - **IMRT QA measurements**
- **Process Improvement**
  - **Bottlenecks**
  - **Safety**

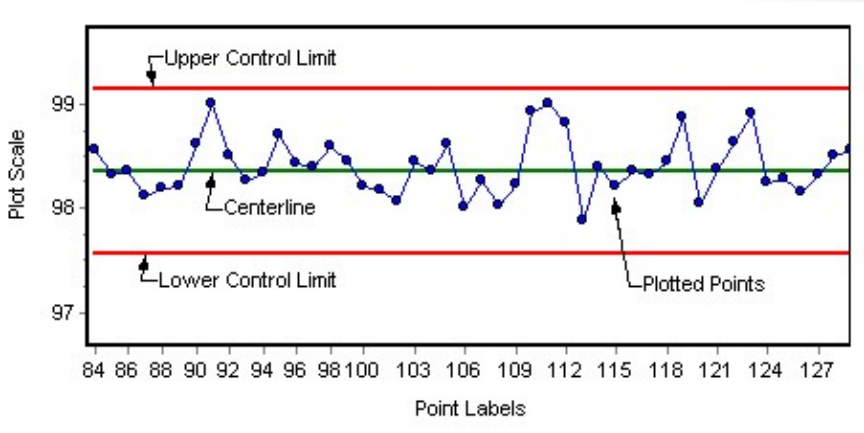


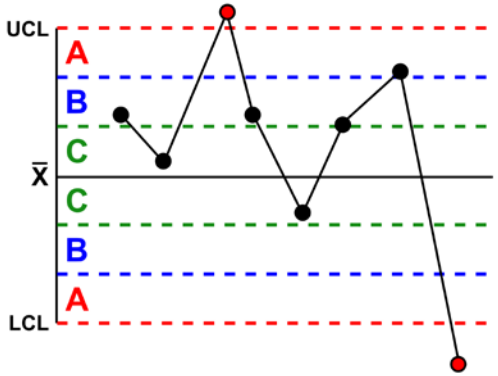




Control Charts

- **Know the purpose of your chart**
- **Understand your data**
- **Plan your response**





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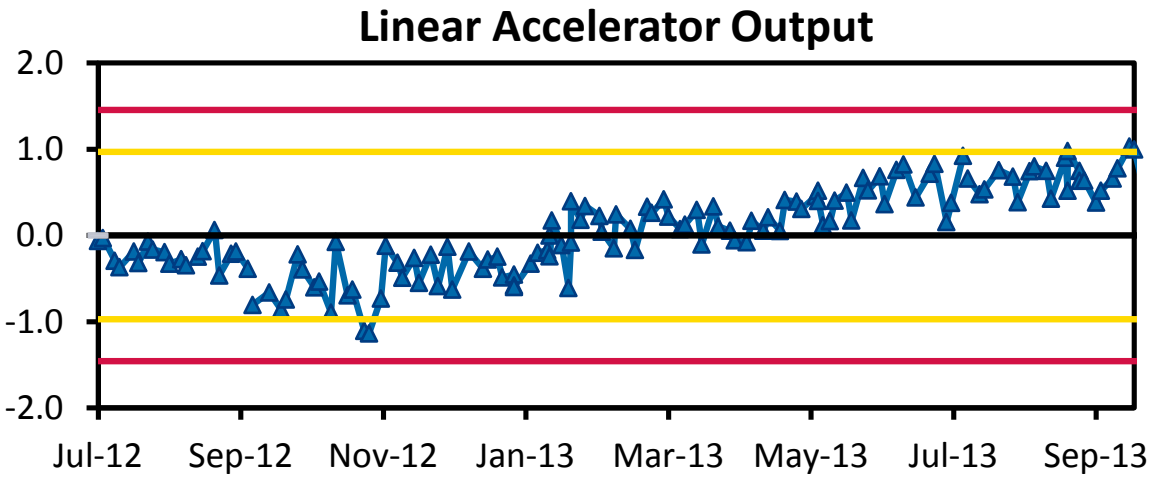
When to Use a Control Chart

- **Controlling and correcting an ongoing process.**
  - **Example: Linac Output**
  - **Particularly useful to identify sudden changes in output**



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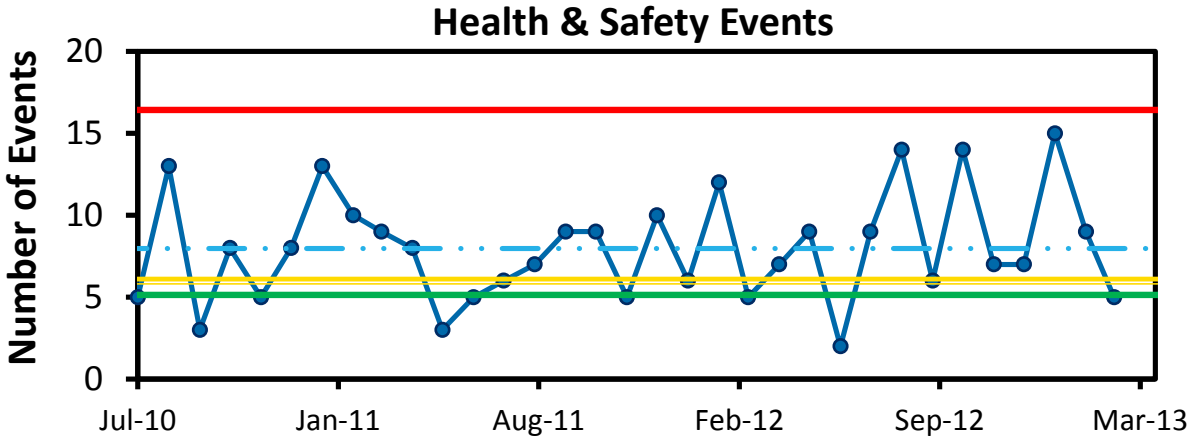
When to Use a Control Chart

- **Testing for system stability**
  - **Example: Number of Health & Safety Events**
  - **Provides expected range in number of events**



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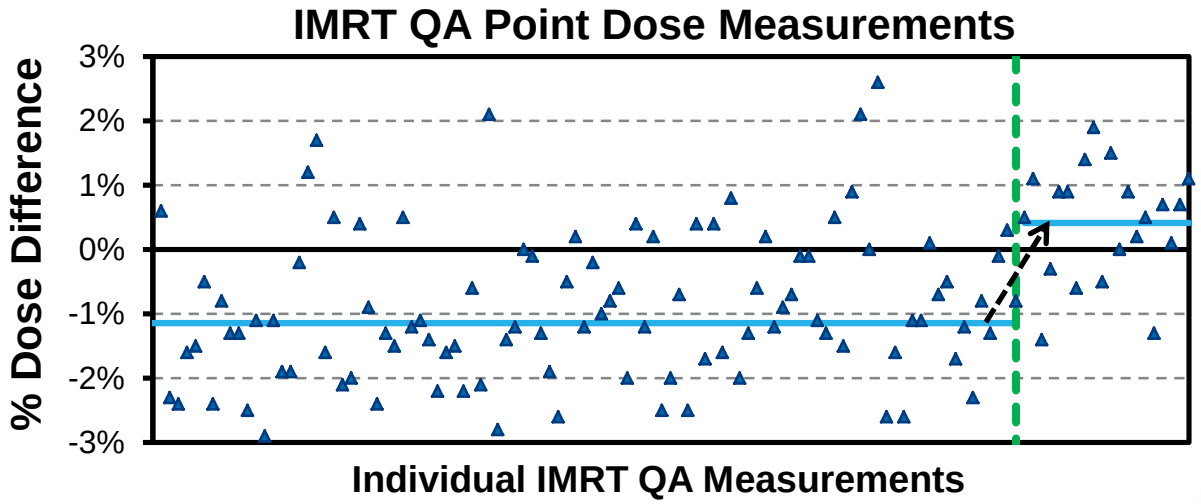
When to Use a Control Chart

- **Analyzing the effect of a change in process**
  - **Example: Change in IMRT QA after TPS upgrade**
  - **Identifies systematic change in noisy data**



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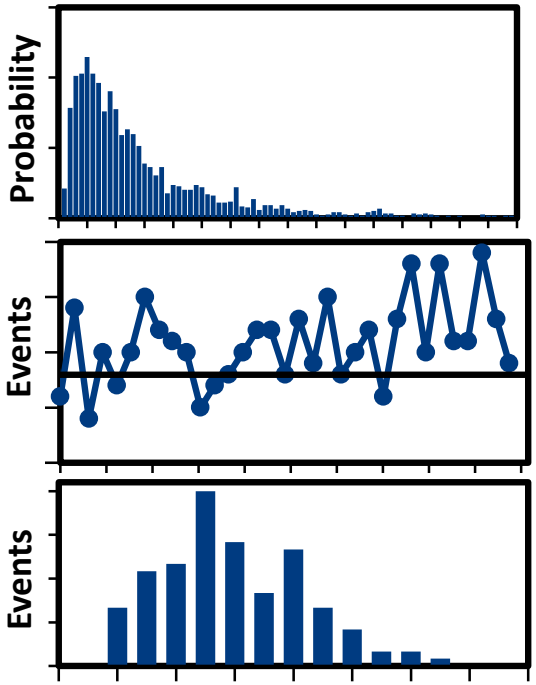
Understand Your Data

- Important Data factors:
  - Data Distribution
  - Degree of variability
  - Bias & Stability



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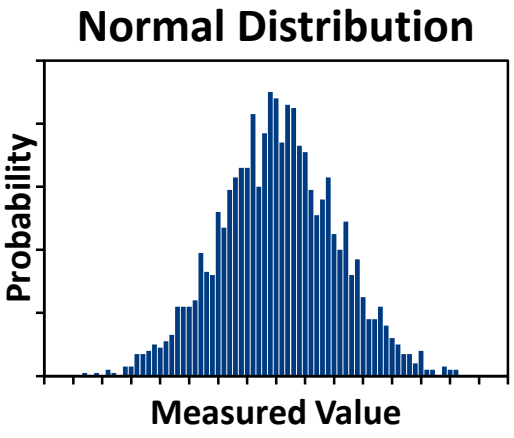
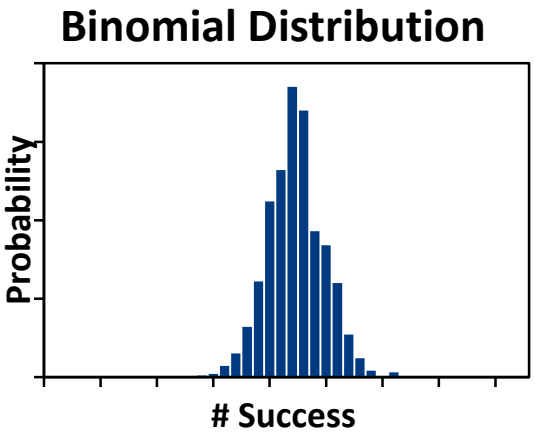
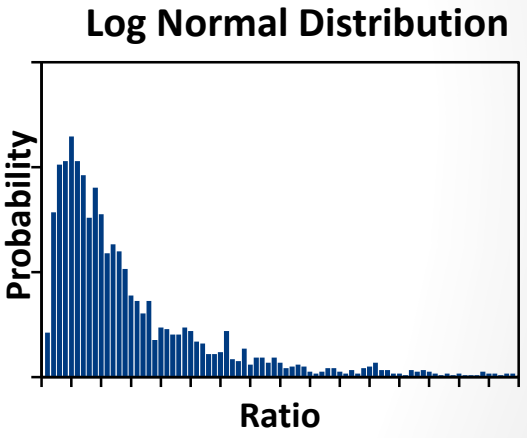
Understand Your Data

- The type of data will drive distribution of the data
- This in turn dictates the appropriate analysis







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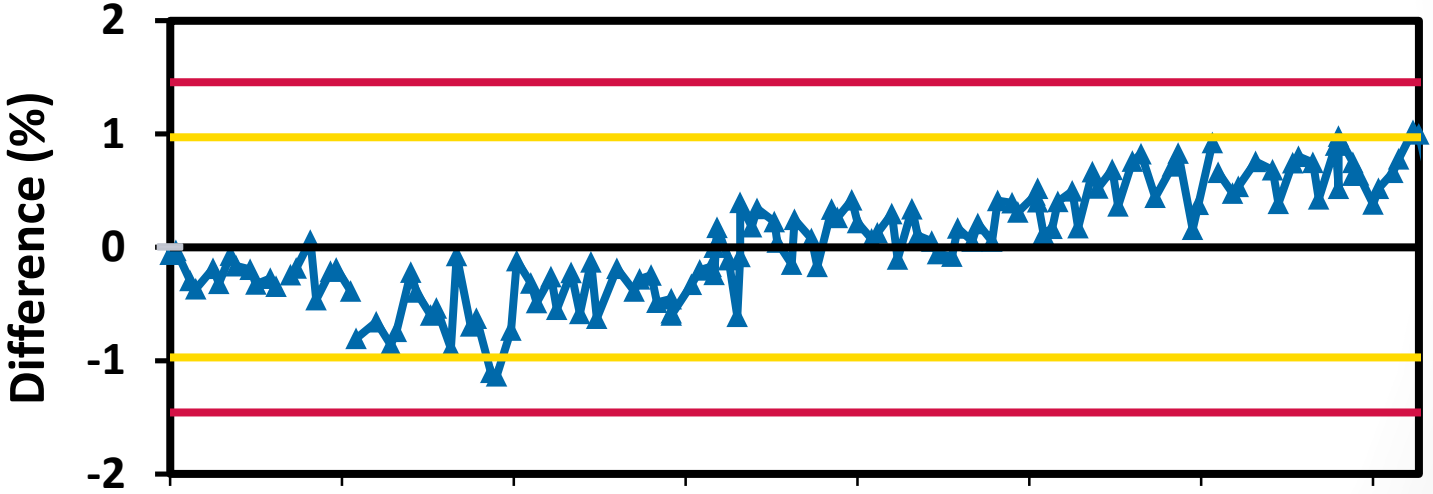
Understand Your Data

- Data variability and goal will dictate sample size
  - Linear Accelerator Output



Variation well below "Tolerance" level of 2% difference

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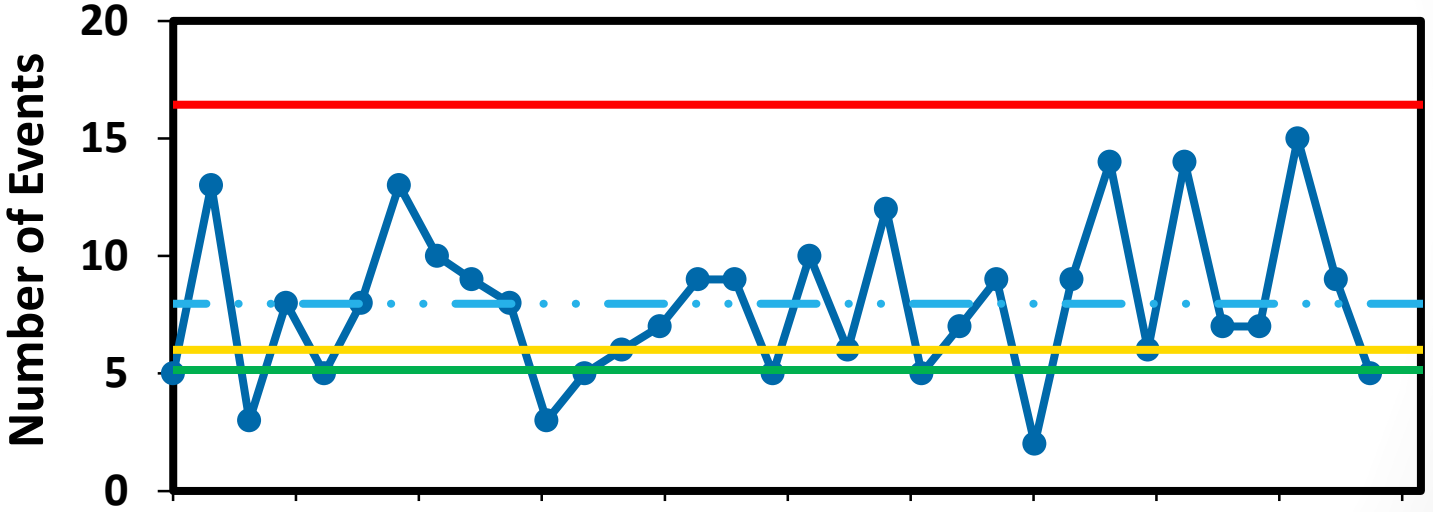
Understand Your Data

- Data variability and goal will dictate sample size
  - Health and Safety Events



Large variation in reported events

Need to average over longer time span

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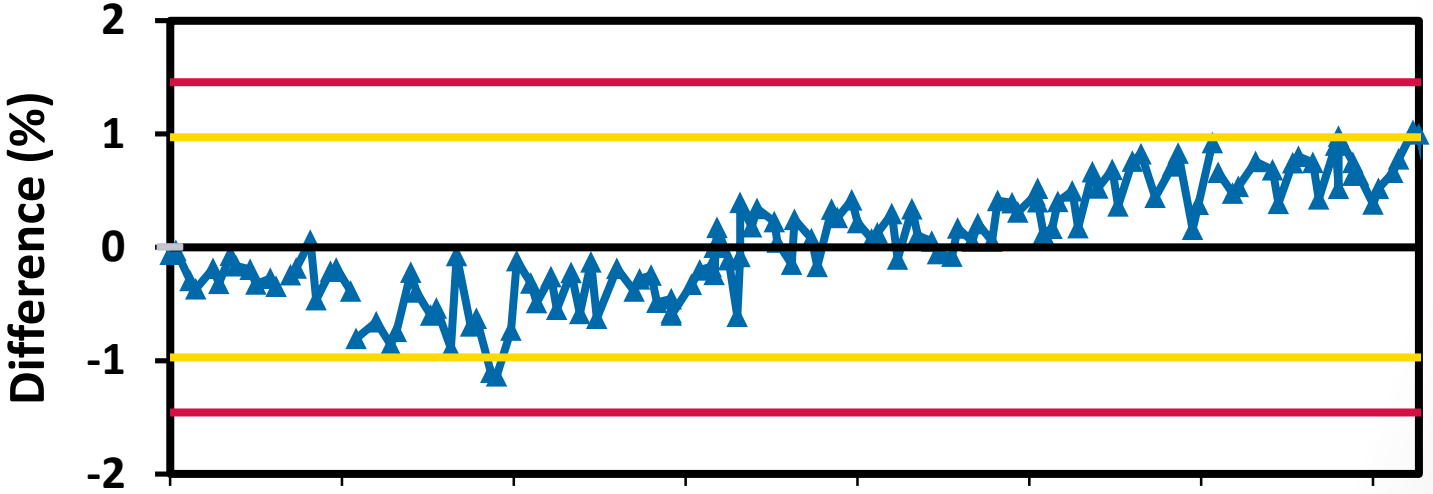
Understand Your Data

- Stability and bias affect interpretation
  - Linear Accelerator Output



The linear accelerator trend increases the control chart limits

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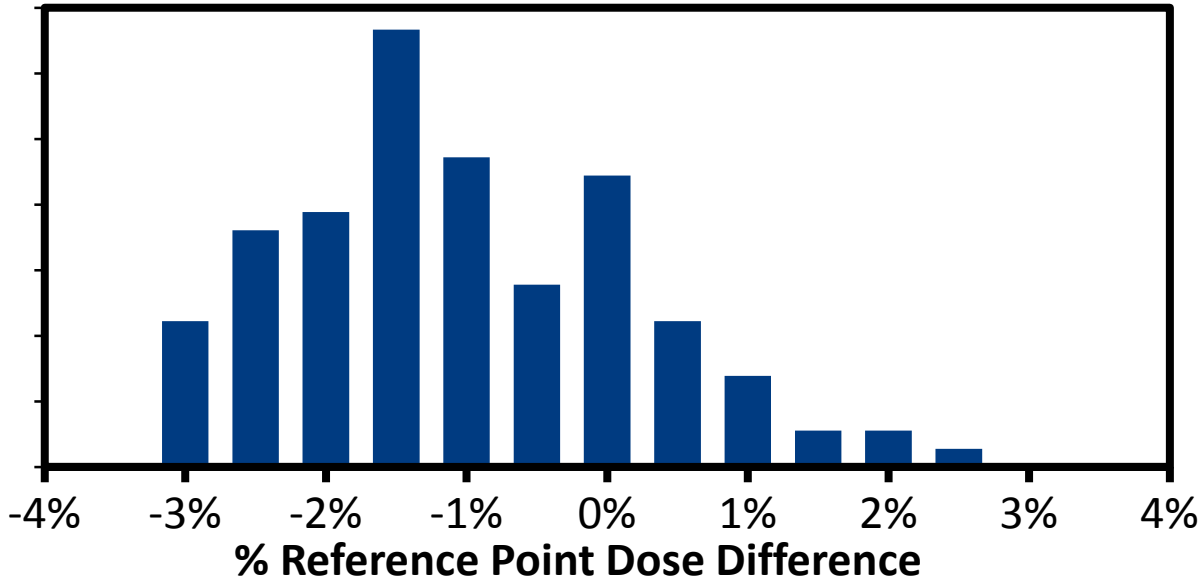
Understand Your Data

- Stability and bias affect interpretation
  - IMRT QA



Selection bias removed data below -3%

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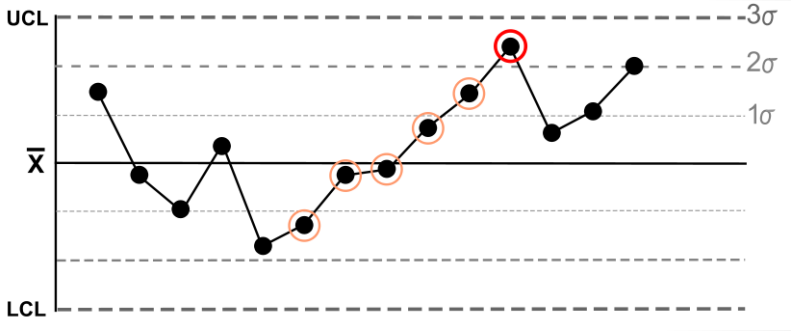
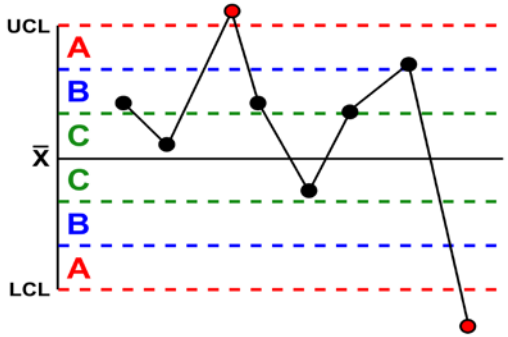
Plan Your Response

- Based on goals, decide a-priori what will be done with the control chart information.
- Identify appropriate action triggers.
  - Thresholds
  - Sudden changes
  - Trends





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Resources for Further Information

- http://asq.org/learn-about-quality/data-collection-analysis-tools/overview/control-chart.html
- http://www.itl.nist.gov/div898/handbook/index.htm
- https://www.moresteam.com/toolbox/index.cfm

- Pawlicki, T. *et al.* Moving from IMRT QA measurements toward independent computer calculations using control charts. *Radiother. Oncol.* **89,** 330–337 (2008).
- Pawlicki, T. & Whitaker, M. Variation and Control of Process Behavior. *Int. J. Radiat. Oncol. Biol. Phys.* **71,** S210–S214 (2008).
- Pawlicki, T., Whitaker, M. & Boyer, A. L. Statistical process control for radiotherapy quality assurance. *Med. Phys.* **32,** 2777–2786 (2005).
- Pawlicki, T. *et al.* Process control analysis of IMRT QA: implications for clinical trials. *Phys. Med. Biol.* **53,** 5193–5205 (2008).

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Summary

- Documents and resources are available
  - Don’t waste your time re-inventing the wheel
- Commissioning should be context based
  - Focus on what you need to know rather than what you need to do.
- Monitor your system and process
  - Control charts need to be planned and understood

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