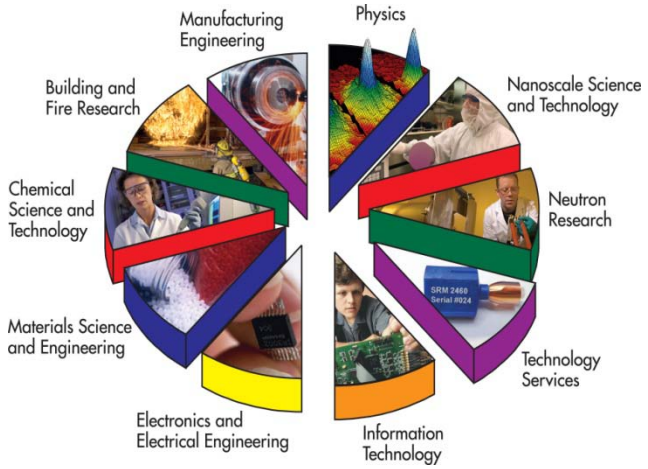
NIST Standards for Radiation-Based Medical Imaging:

toward harmonization



National Institute of Standards and Technology

NIST

...working with industry to foster innovation, trade, security and jobs

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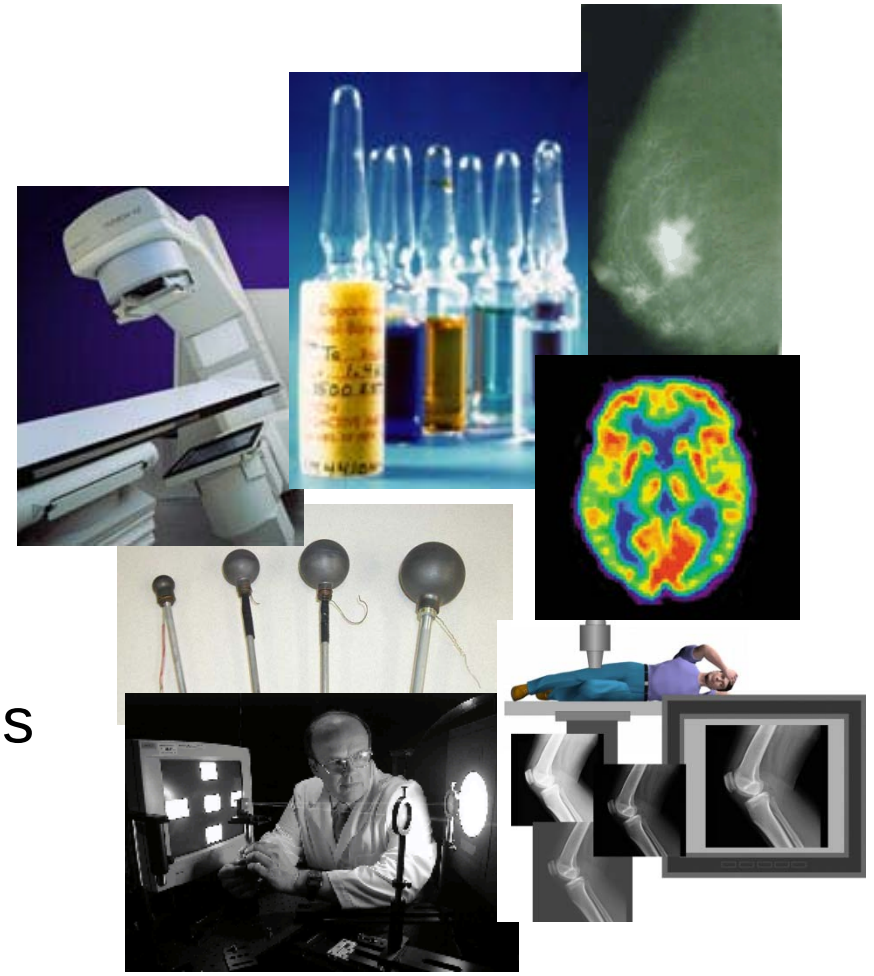
Where NIST Fits In

- Long history in
  - Methods development
  - Standards and calibrations (radionuclides, X-ray beams)
  - Tech transfer and support
- Expanding applications
  - Budget initiative in 2007, plans beyond
  - Physical measurements for bio/med



Providing critical measurement infrastructure for biological imaging

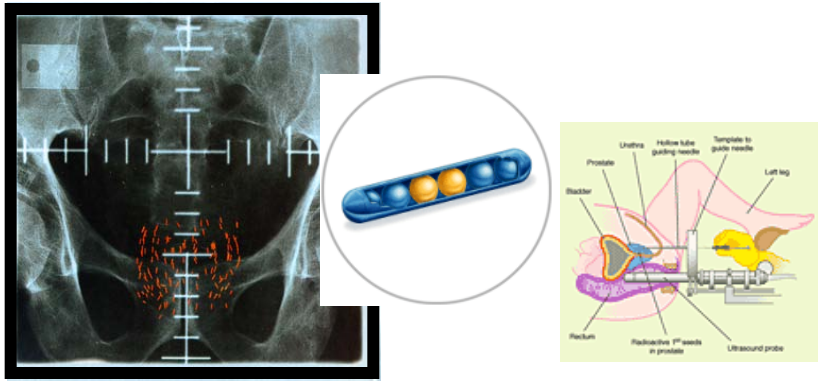
NIST Measurement Standards

Health Care

Radiation Physics

Theoretical dosimetry

Codes and models

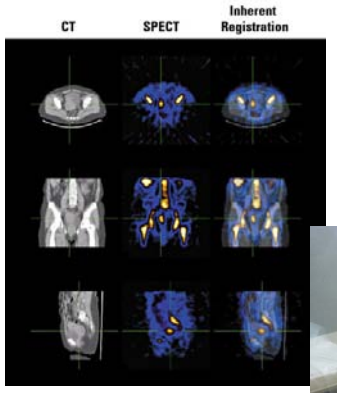


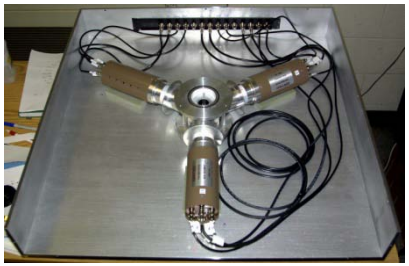
Measurements for dosimetry

Brachytherapy

X-ray calibrations

Standards for mammography





Radionuclide metrology

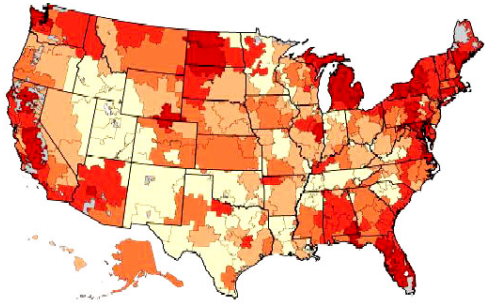
Radionuclide standardization

Standard Reference Materials

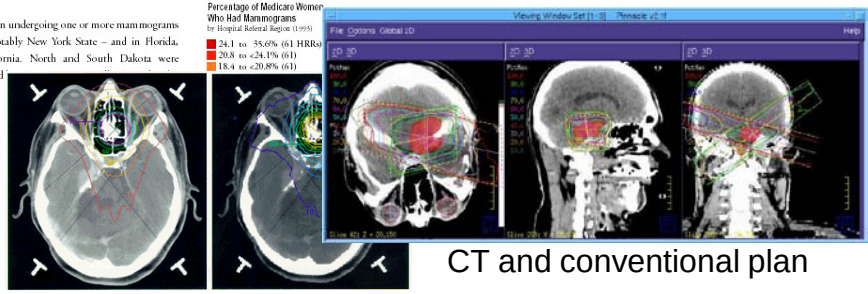
Calibrations

Metrology for Diagnostics

- Mammography
- Conventional x rays
- Spiral CT
- Theoretical Dosimetry
- Imaging radionuclides, etc.




Conformal radiation therapy


CT and conventional plan

Instrument Calibrations Required by Mammography Quality Standards Act

- 1992 Law requires proficiency testing of mammography instruments
- NIST and FDA developed necessary calibration facilities
- 4 manufacturers and FDA now meet the legal requirements
- 3 AAPM Accredited Dosimetry Calibration Labs

Partners in Measurement Standards

Together Towards Harmonization

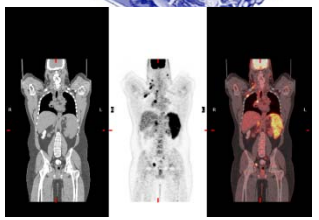
- Medical Applications Subcommittee CIRMS
- Radiation Therapy Committee AAPM
- Industry (manufacturers)
- Academia
- FDA CDRH
- NIH (NIBIB, NCI)
- Other community groups (PCF, ATA, ISCD, SNM, RSNA, etc.)

16th Annual Meeting

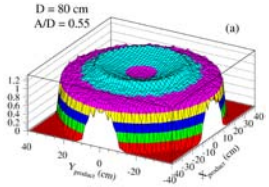
COUNCIL ON IONIZING RADIATION MEASUREMENTS AND STANDARDS

CIRMS

2007



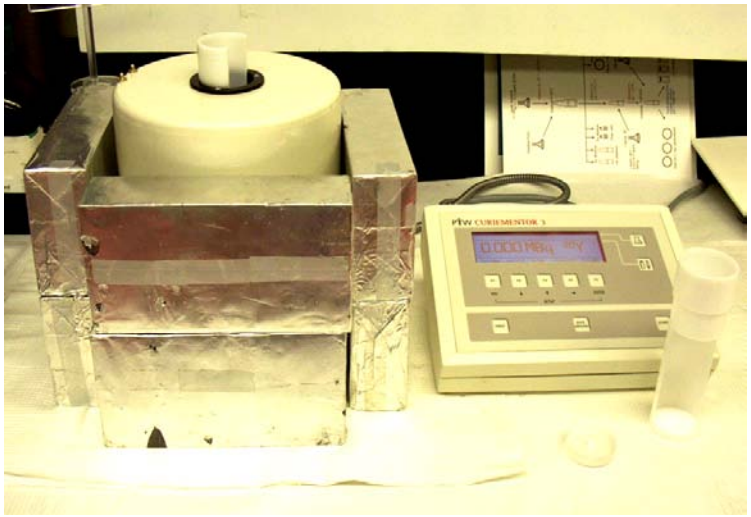
Measurements and Standards for Radiation-Based Imaging

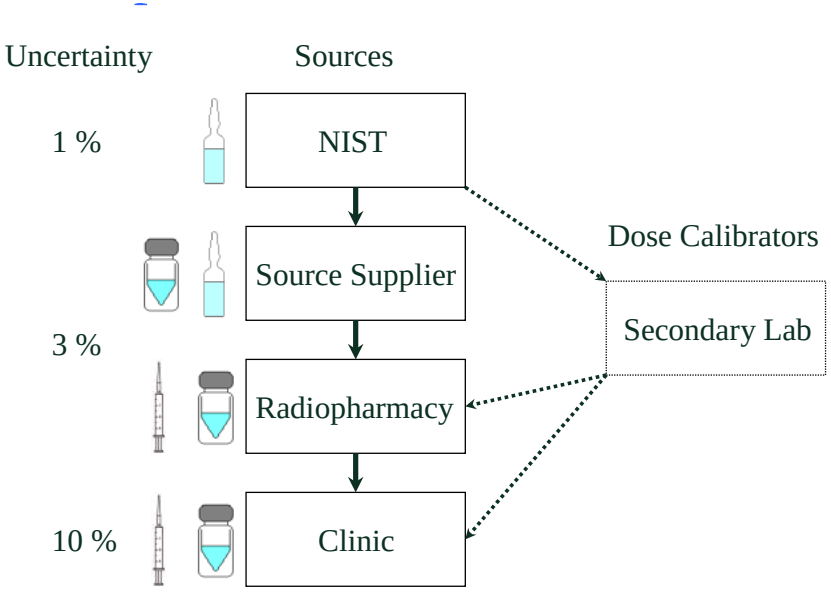


October 22-24, 2007

Collaborations with Stakeholders
Reducing Uncertainties

- Development of primary standards
- Development of transfer standards and calibration factors
- Protocol development for instrumentation, procedures
- Measurement assurance programs for traceability





Why Now

NIST asked by representatives of the drug industry, the NCI, the medical imaging industry, and various professional organizations such as the Radiological Society of North America to provide***:

- **Physical standards and calibration tools for quantitative imaging and change measurements in therapy:**
  - PET/CT/MRI, spiral CT, bone health, optical imaging
- **Standards for image generation, transmission, archival storage and dissemination to researchers**

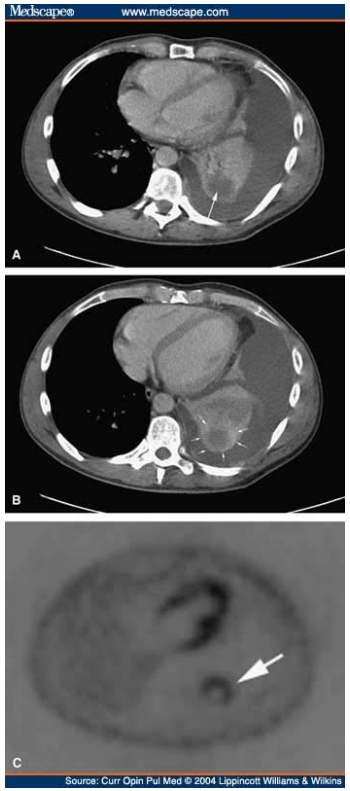
2006 Workshop, ***Imaging as a Biomarker: Standards for Change Measurements in Therapy…….**NIH, RSNA, PhRMA, FDA, et al.**

Technical Opportunity

Where standards enable the technology

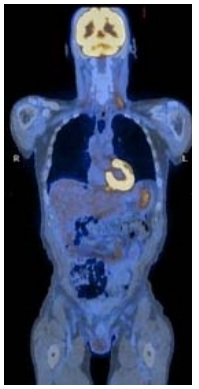
Do you see it? What is it? Where is it?
Has it changed? What's it up to?
Just how much radiation do I have to get???

Quantitative imaging needed for treatment planning, patient evaluation, drug development, clinical trials



Quantitative PET/CT

Seeing the same thing the same way



- Usefulness depends on *consistent subject data* (time and distance)
- *Persistent variability* in results from PET/CT images (in addition to subject variability)
  - Between clinical sites
    - Activity calibration (injected or in phantom)
    - Conversion of image intensity to activity
    - Protocols for acquisition, reconstruction, analysis
  - Between scanners
    - Conversion of image intensity to activity
    - Different reconstruction algorithms
  - Between scans
    - Activity calibration (injected or in phantom)
    - Conversion of image intensity to activity

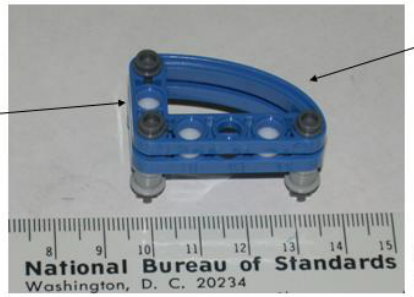
Calibration traceable to national standards for more quantitative results in patient assessment, drug development, and treatment planning

Progress with CT

Size and Dimension

- Recognized need for length standard
  - Tumor definition
  - Tumor size
  - Cheap, portable
- NIST-designed “pocket-phantom”
  - Very inexpensive
  - Robust
  - Good contrast
- Status
  - Dimensional accuracy NIST-traceable
  - LEGO® pieces about 0 H.U.
  - Teflon balls about +800 H.U. (±25%)
  - Difference estimated at ±100 H.U.
  - Positive feedback from stakeholders
  - Redesigned CT phantom (looking to evaluate in clinical trial using CT)

Proposed CT phantom to provide a length scale in the 1 cm range



6.35 mm dia. ±0.025 mm Teflon balls (can use other materials e.g., glass or sapphire with 5.5 mm to 6.5 mm diamater)

Fixture from LEGO Technic parts, accurate to 0.01 mm

Rings hold balls accurately

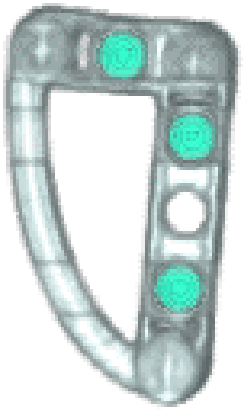
Find centroids in reconstruction. Their differences are the length scale.

Expect dimensions of centroid accurate to 0.05 mm to 0.1 mm

Parts cost: $1 to $60 depending

Fixture absorbs x-rays similar to water

Balls absorb x-rays similar to bone

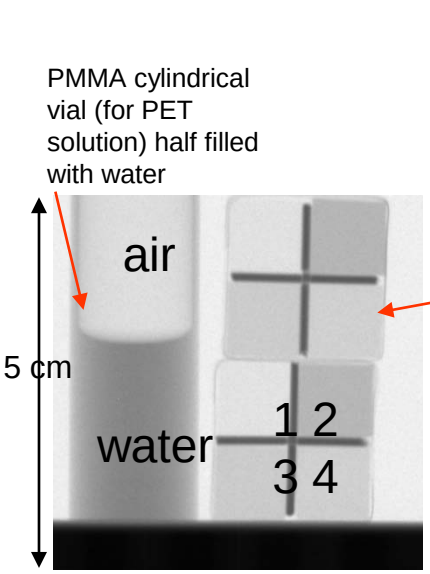


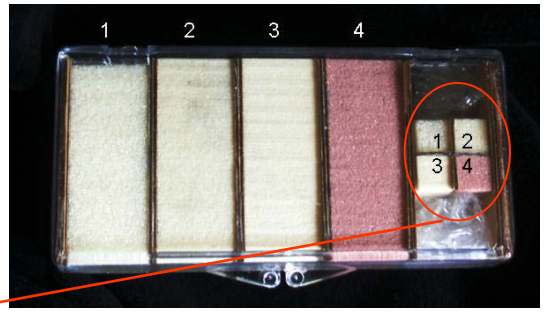
3D visualization reconstructed from CT images

Progress with CT

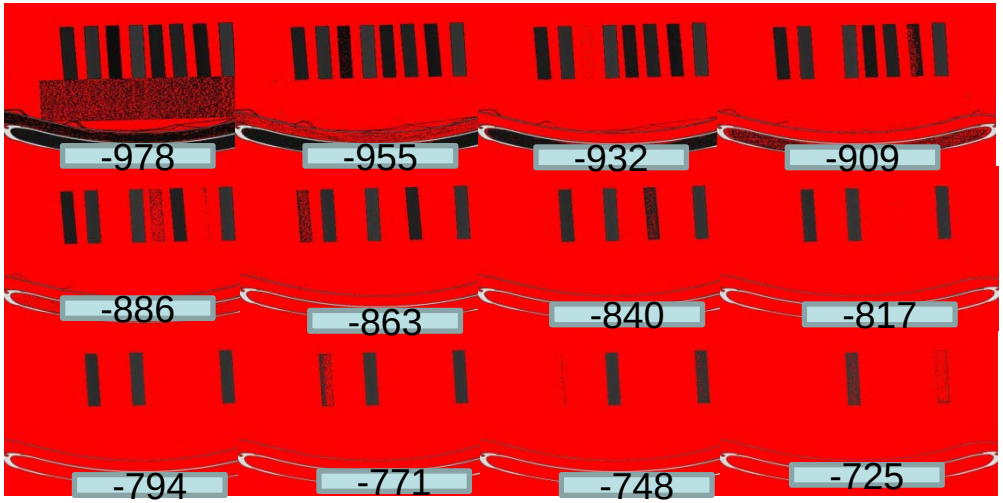
Density and Contrast

- Need for tissue contrast
  - Particular in lung imaging
  - H.U. variability across tumor dimension
- NIST evaluated “foam”
  - NIST-standard x-ray beam
  - Good contrast
  - Wide density range
- Status
  - Foam densities visible at various thresholds
  - Good separation (23 H.U. steps)
  - Paper published, appears to be in use





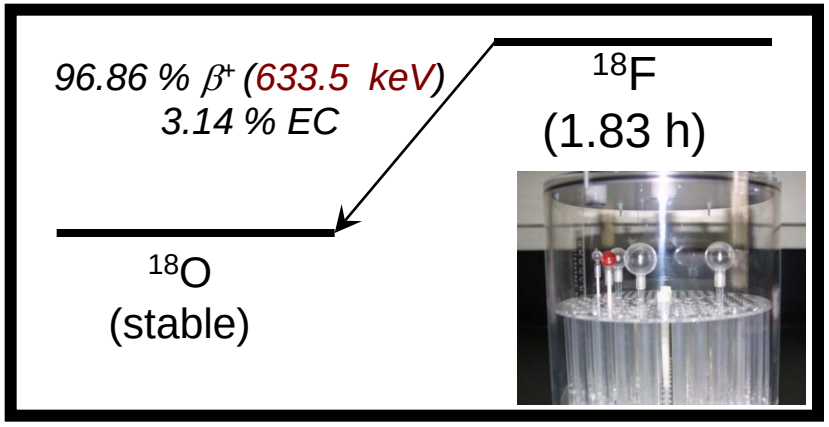
X-ray transmission images of foam samples

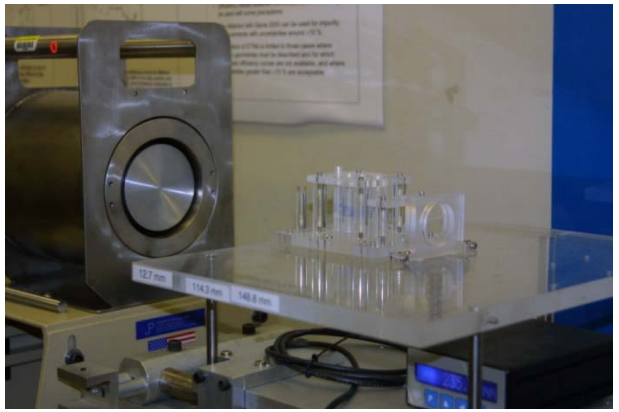


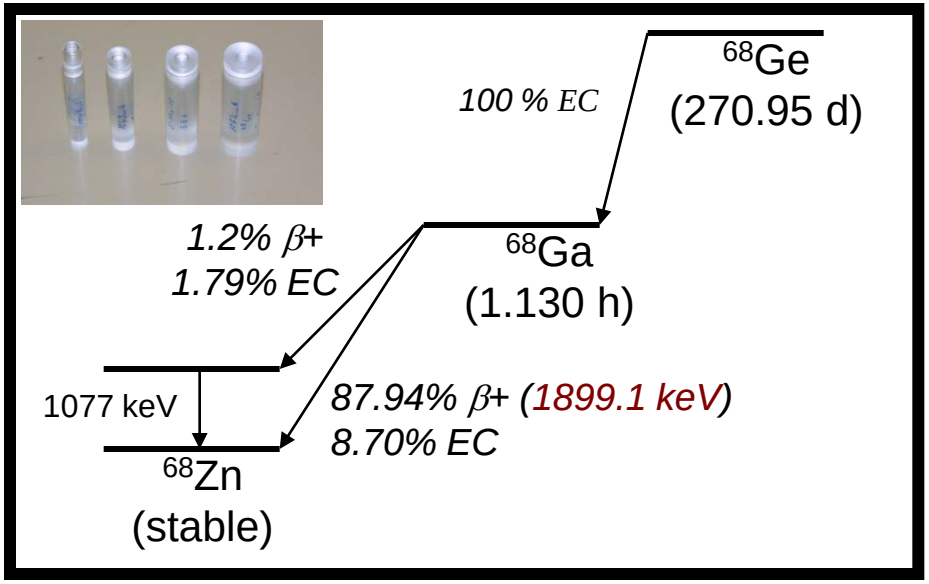
Progress with PET

Traceability Despite 2-hour Half-Life

- Input from stakeholders show needs
  - Traceability for instrument calibration
  - Longer-lived
  - Phantom variety
  - Protocols for use, training
- Ge-68 ($t_{1/2}$ 271 d)
  - National standard
  - Calibration for different geometries (syringe, phantoms)
- Status
  - Calibration transferred to NIST Secondary Standard Ionization Chamber (routine future calibrations)
  - Calibrated ^{68}Ge phantoms (same tech – epoxy - as mock syringes)







Progress with PET

Determination of response factor ^{18}F relative to ^{68}Ge

Total of 5 mock syringes + 1 NIST ampoule gravimetrically prepared from [^{18}F]DG

↓

Activity conc. determined from ampoule (traceable to National Standard)

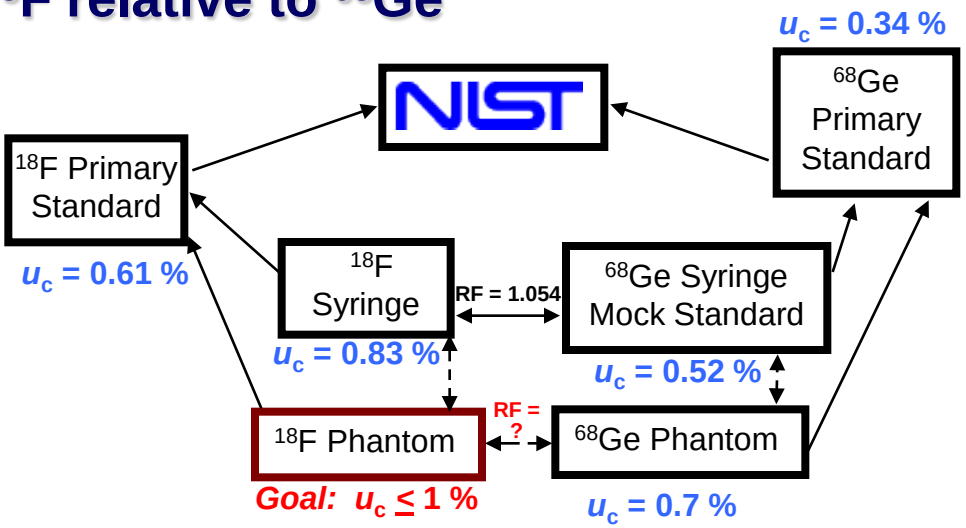
↓

Activity in each syringe calculated; each source measured in ionization chambers.

↓

Response of ^{18}F at different calibration factors compared with liquid and solid ^{68}Ge sources.

Measured rel. resp. = 1.054 ± 0.020; Monte Carlo predicts 1.053



Measurement Error Uncovered for ^{18}F

- Traceable ^{68}Ge mock-syringes sent to 3 clinical sites (40+ dose calibrators)
- Measurements made at manufacturer-recommended settings for ^{18}F
- Comparison with NIST traceable activity value for ^{18}F (from relative response factor)
- Total of 31 independent measurements
- Results were all 5-6 % high

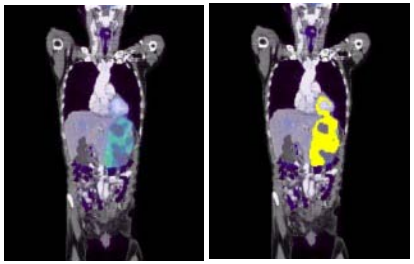
Collaboration Opportunities

Harmonization across the community

- Planned expansion (DXA, PET/MRI, change analysis, and personalized nuclear medicine)
- Interactions with other agencies and stakeholders to address clinical needs (FDA, NIH, NCI, CIRMS)
- Established and growing laboratory facilities for
  - Guest researcher opportunities (visiting scientist)
  - Technical discussions, combined “problem solving”
  - Cooperative research (“CRADA”)
  - Measurement traceability and SRMs in-place
  - Pending acquisition of PET/CT scanner
- Long-standing international interactions

radioactivity

contrast



“closing the loop”

Measurement foundation to enable standardization among centers:
Quantitative imaging traceable to National standards

Contact Information

For further information contact:

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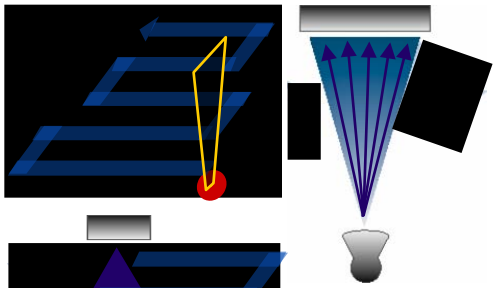
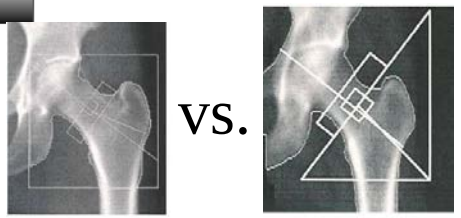
http://physics.nist.gov/Divisions/Div846/div846.html

Metrology for X-Ray-Based Bone-Density Measurements

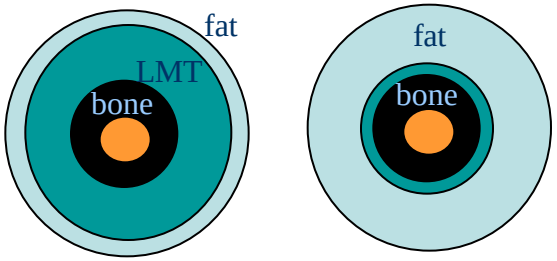
- **Problem**: Better assessment of bone health
- **Today**: Uncoordinated approach using manufacturer-developed phantoms to calibrate system-specific instrumentation
- **Goal**: Absolute, well-characterized phantoms, traceable to National standards, for confidence in calibration for a range of instruments/systems
- **Success**: Reduced variability among instruments due to system-specific technical and engineering issues.
- **Impact**: Reduction in bone disease impact, including fracture, for an aging population.
- **Why NIST?** Unique expertise in physical metrology and recognized role as “honest broker” for industry



Acquisition



Interpretation



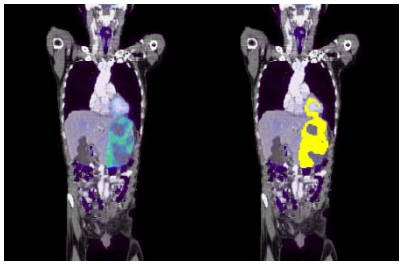
Personalized

Standards for Quantitative PET-MRI

- **Problem**: No phantoms for combined PET-MRI available (on the rise)
- **Today**: No institution working on development of calibrated dual-modality phantoms
- **Goal**: Quantification of medical images in terms of spatial dimension and contrast/positron emission intensity
- **Success**: Appropriate standard phantoms and their adoption in practice
- **Impact:** Ability to calibrate PET-MRI scanners traceable to National standards
- **Why NIST?** National standards for physical quantities (esp. radioactivity, dose, and length) crucial to medical imaging and patient safety

radioactivity

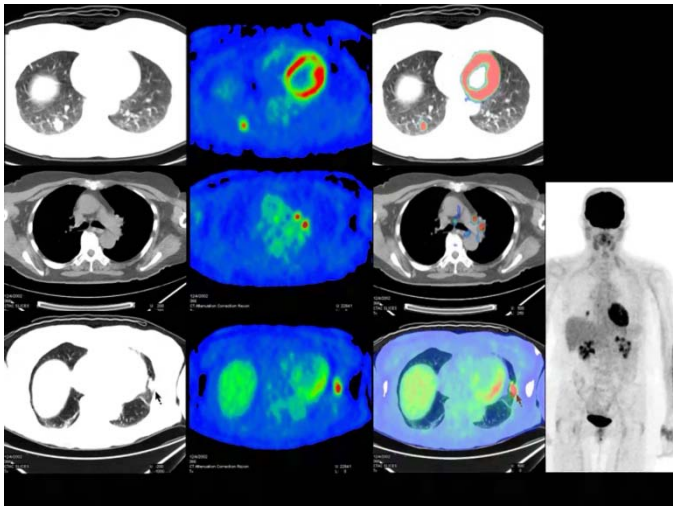
contrast



"closing the loop"

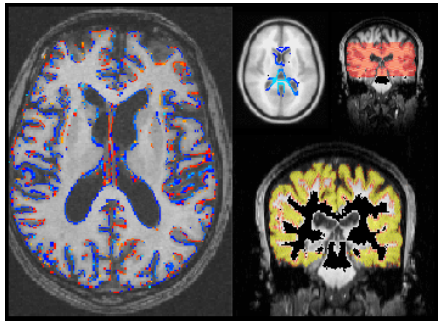
Personalized Nuclear Medicine

- **Problem**: Current guideline based on clinical data and assumptions
- **Today**: Estimations based on internal dosimetry *models*
- **Goal**: Development of new standards for patient-based quantitative nuclear medicine imaging
- **Success**: Development and adoption of appropriate standards
- **Impact:** Safer and more effective treatment for the over 1.4 million US patients diagnosed with cancer each year
- **Why NIST?** Unique neutral position to objectively compare current methodologies



Standards and Methods for Change Analysis

- **Problem**: Imaging currently limited by ability to discern only large changes in size/metabolism as a *direct consequence* to lack of standards to monitor equipment performance
- **Today**: No institution working to address intrinsic variability due to difference in scanner performance and lack of calibration
- **Goal**: Development of calibration standards, implementation of proficiency testing scheme, work with clinicians, drug and instrument manufacturers to assess needs
- **Success**: Standards adoption in practice, and participation in proficiency tests by major clinical centers
- **Impact:** Billions of dollars saved by drug companies
- **Why NIST?** Neutrality allows NIST to play a unique role in administering proficiency tests



SIENA