Development of a biplane fluoroscope at the VA Puget Sound

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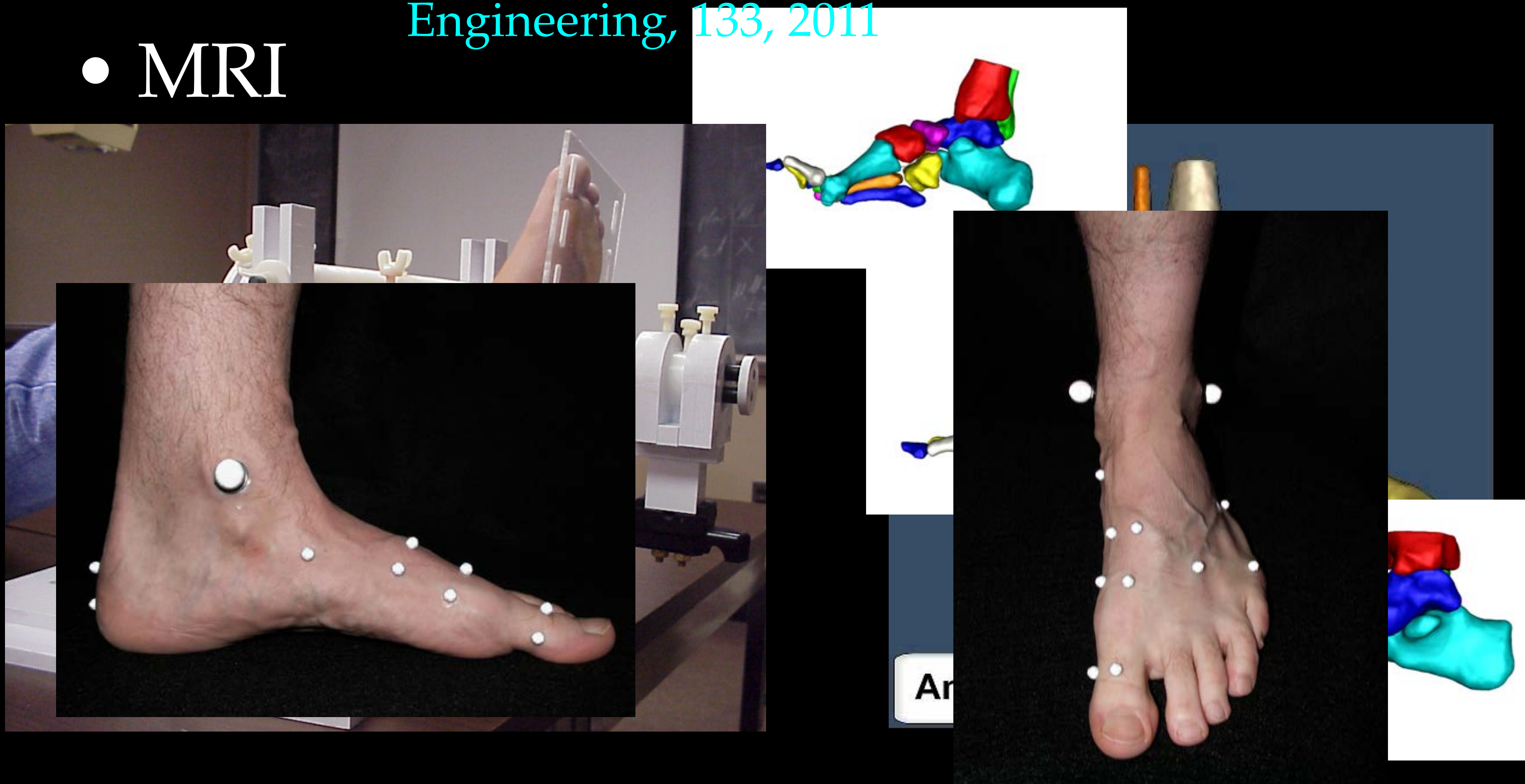
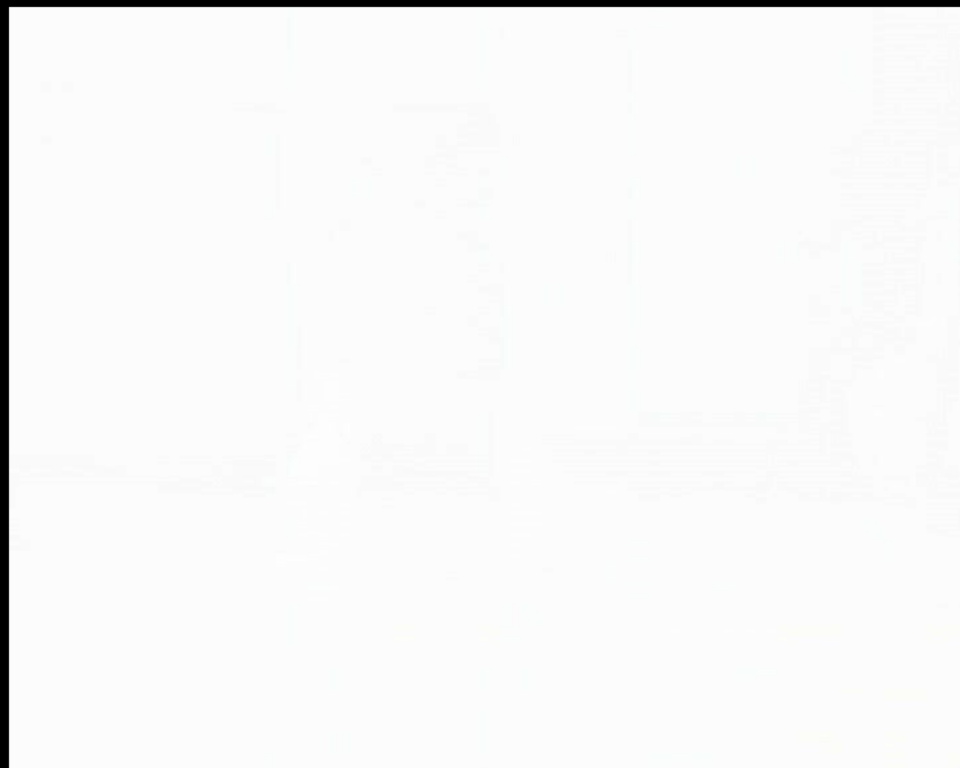
Motivation for biplane fluoroscope development

- CT
- MRI

Whittaker EC, et al., Gait and Posture, in review 2011
Ledoux WR, et al., J Orthop Research, 24, 2006
Fassbind MJ, et al., J of Biomechanical Engineering, 133, 2011



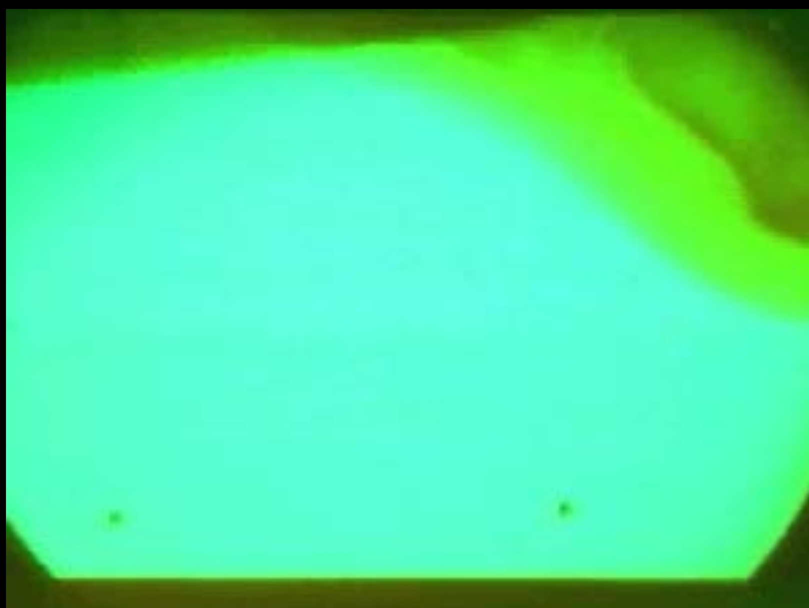
Bone pins

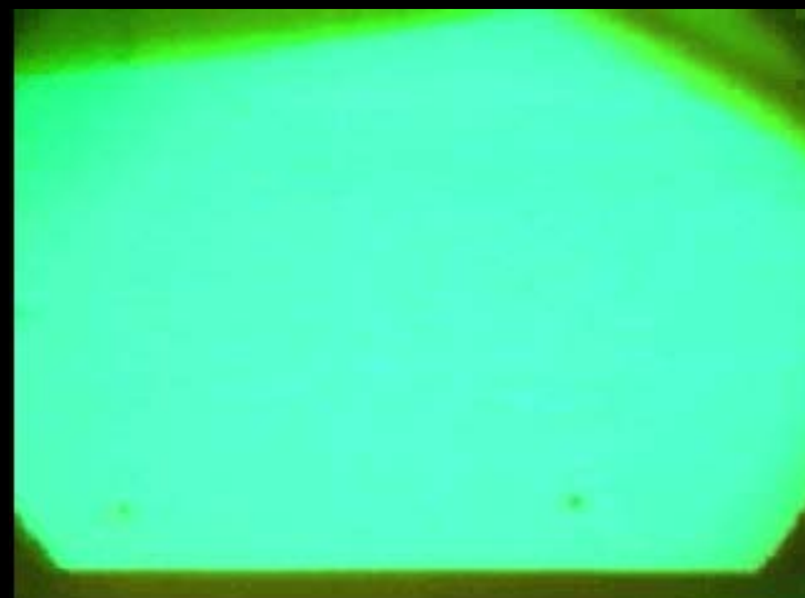


Arndt et al., 2007

Invasive; not used for routine clinical care

Fluoroscopy systems





De Clercq et al., 1994

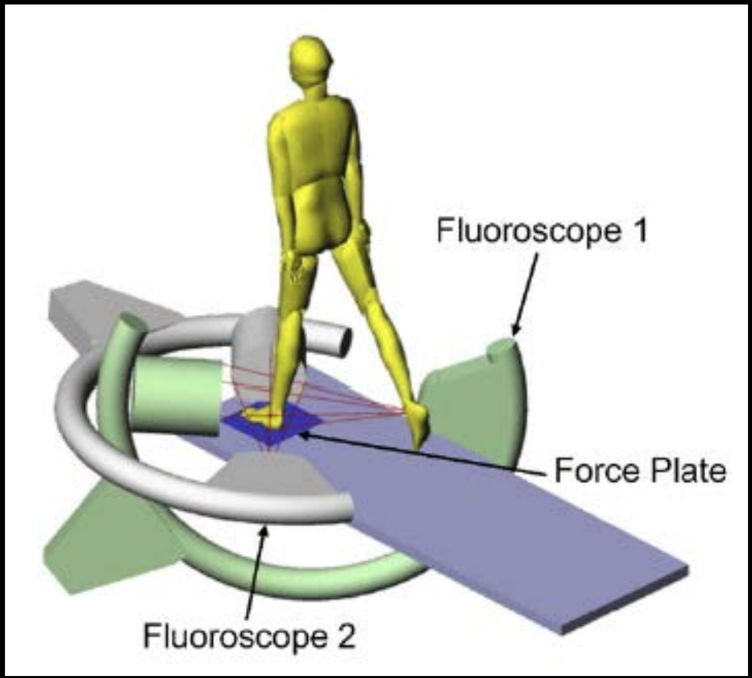
Single plane; exposure to radiation

Fluoroscopy systems

Yamaguchi et al., 2009

hindfoot only; exposure to radiation; 3D-2D

Fluoroscopy systems



Li et al., 2008

Caputo et al., 2009

Portion of stance; exposure to radiation

Biplane fluoroscopy

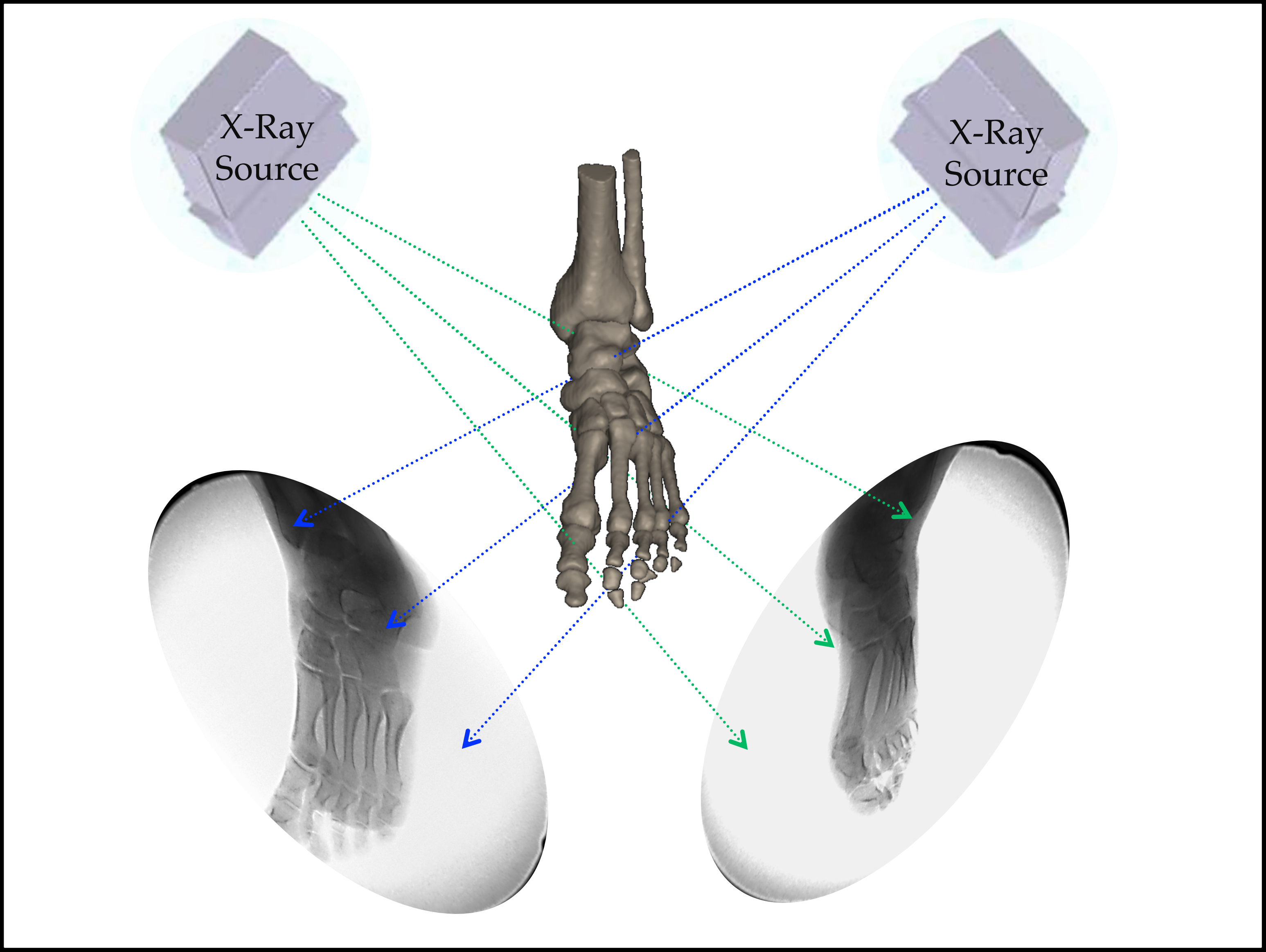
- Custom biplane room too expensive
  - Henry Ford Hospital, U Pittsburgh, Brown
- C-arms
  - Mass General Hospital, Duke
- Modify existing C-arms
  - Steadman-Philippon Research Institute
- Hardware:
  - Two Philips BV-Pulsera C-arms
- Software:
  - Customized

Biplane fluoroscopy

Biplane fluoroscopy

Biplane fluoroscopy

Biplane fluoroscopy

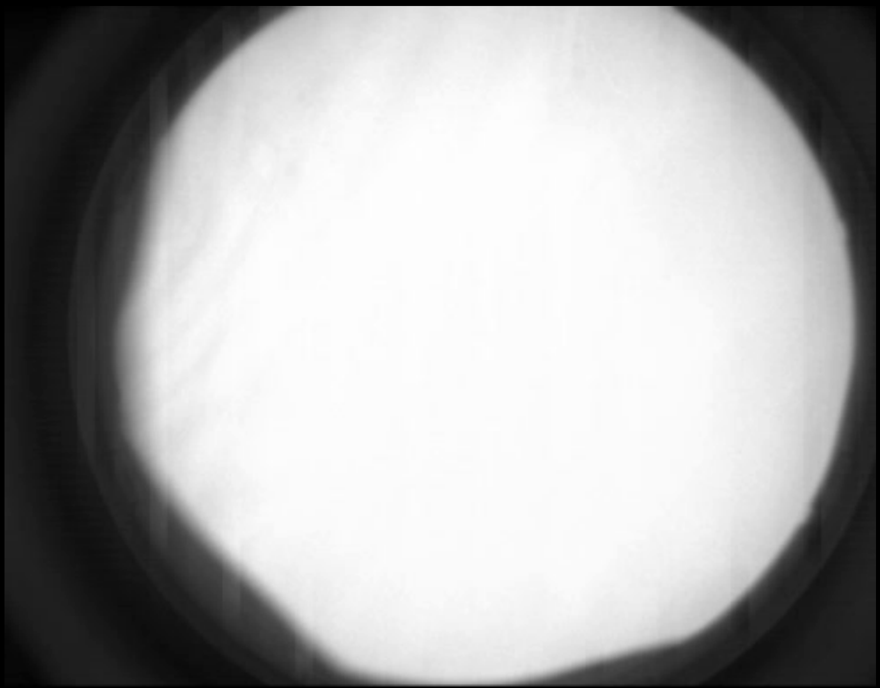


Foot phantom

www.phantomlab.com

Dynamic data collection

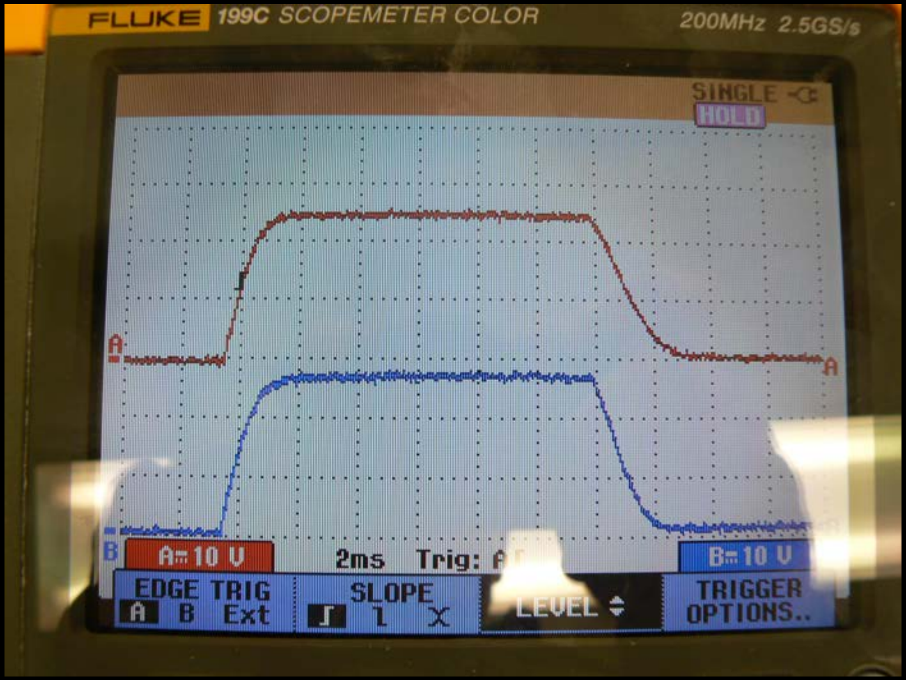
Biplane fluoroscopy

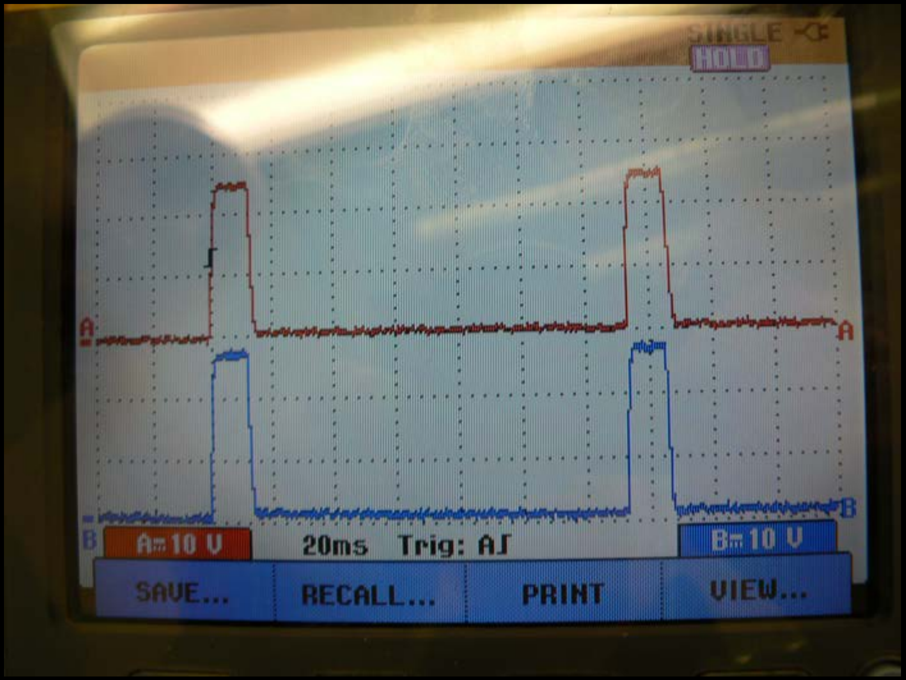


Philips BV Pulsera C-Arms

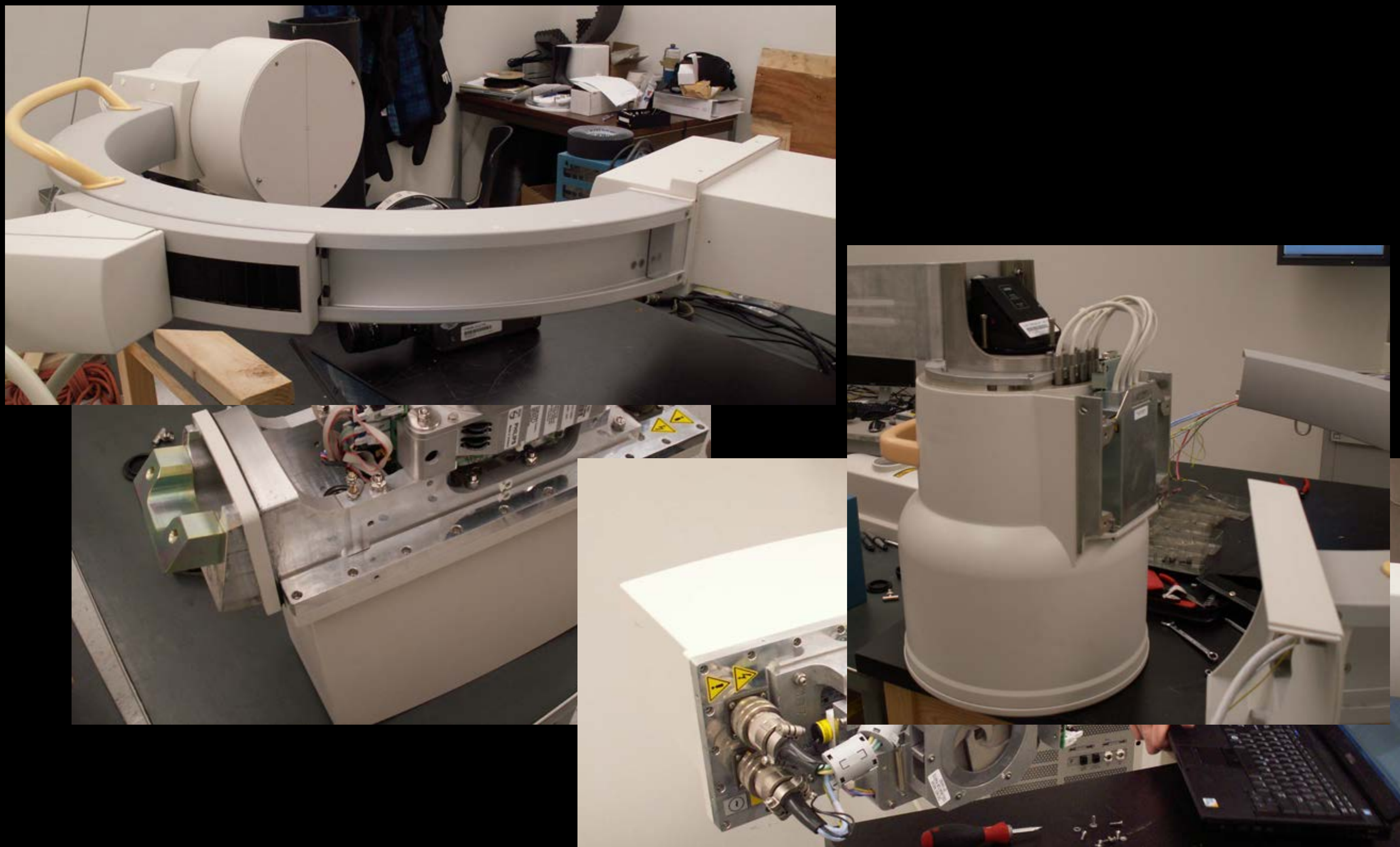
- Typical hospital C-arm
- 30 pulses/s or continuous

Synchronizing systems

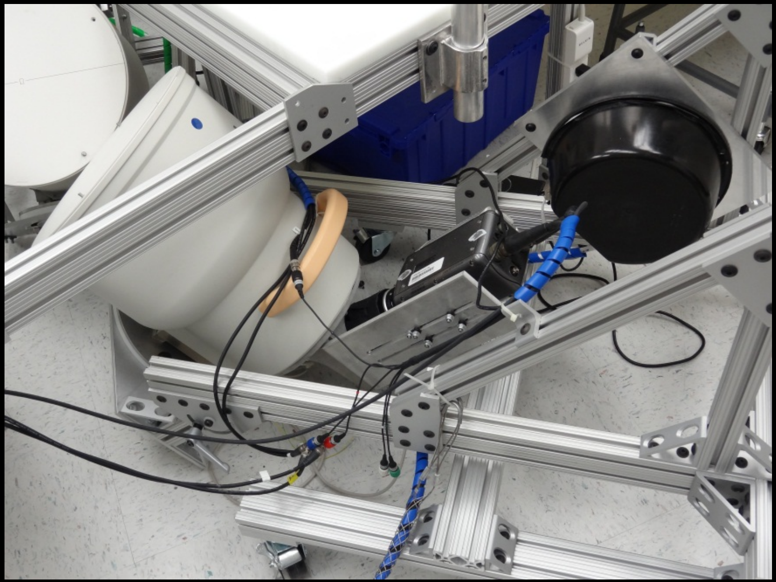
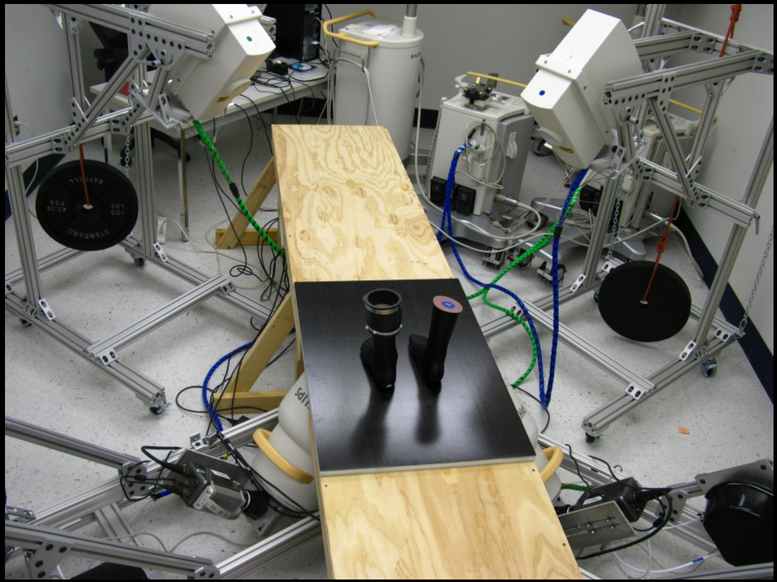
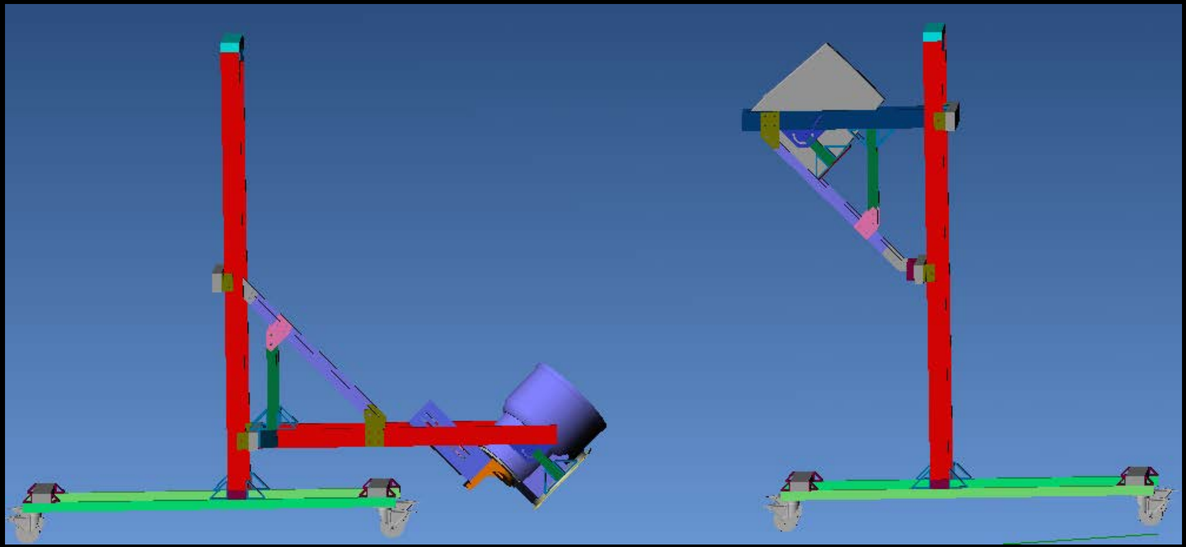
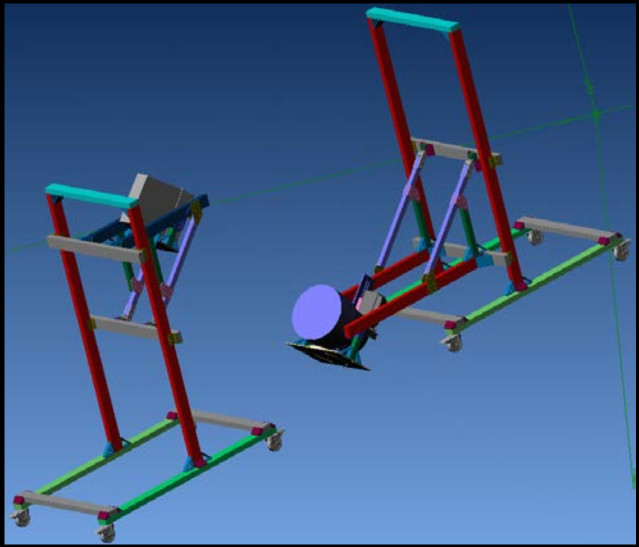




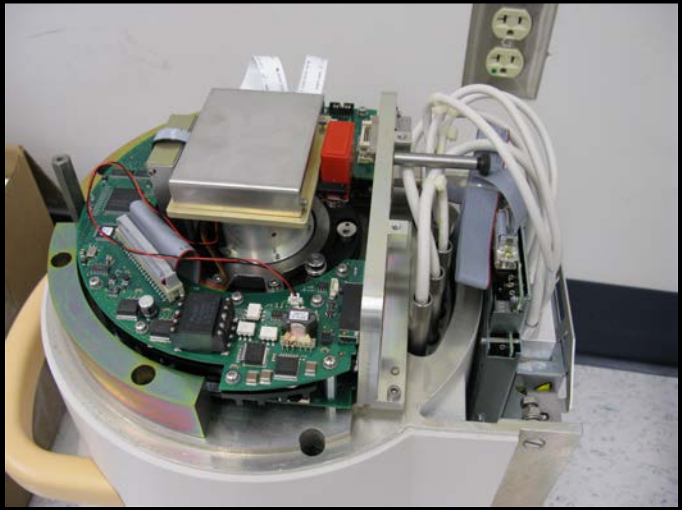
Disassembling C-arms

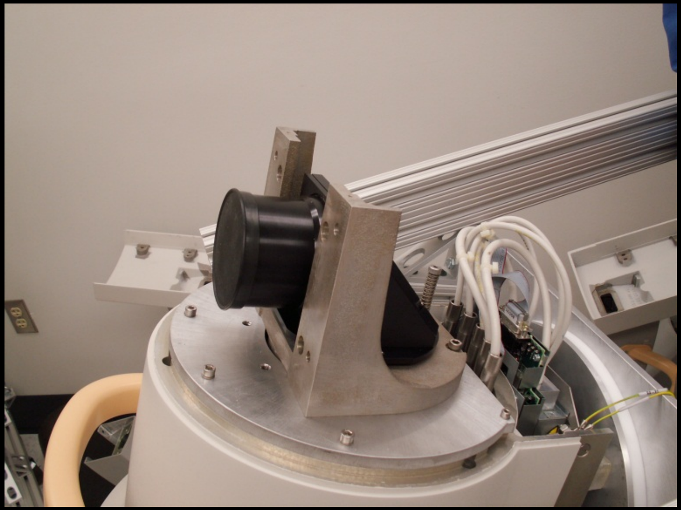
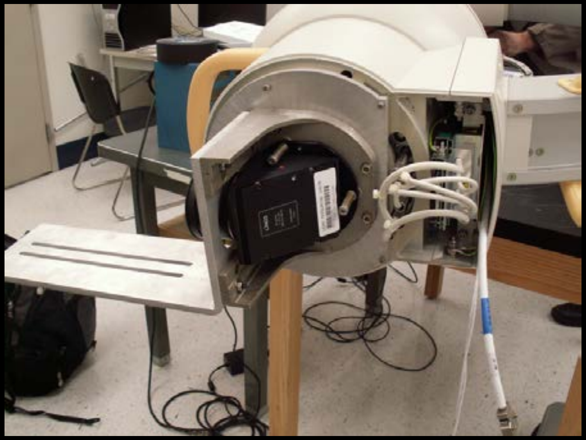


Custom mounting devices

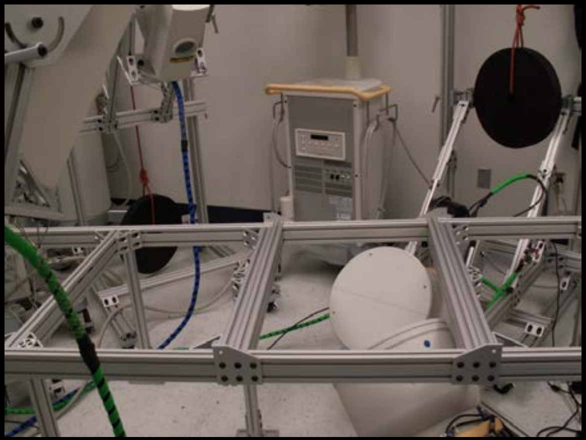





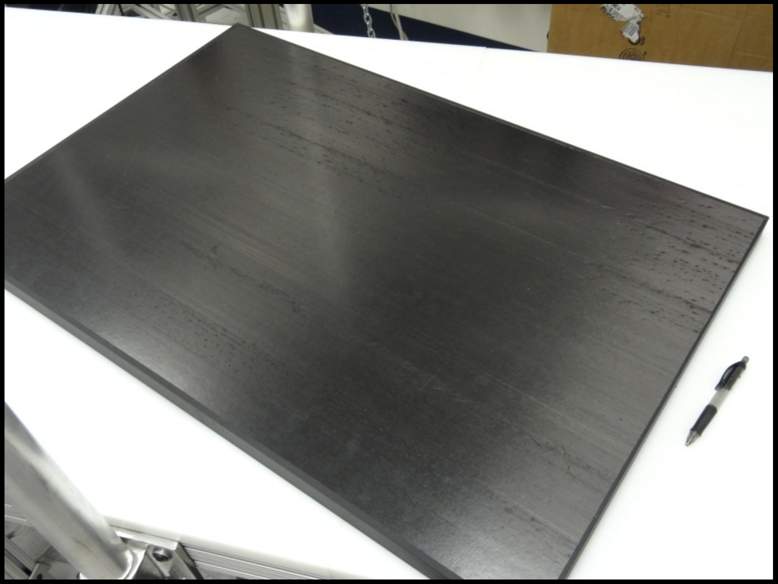
Replacing cameras

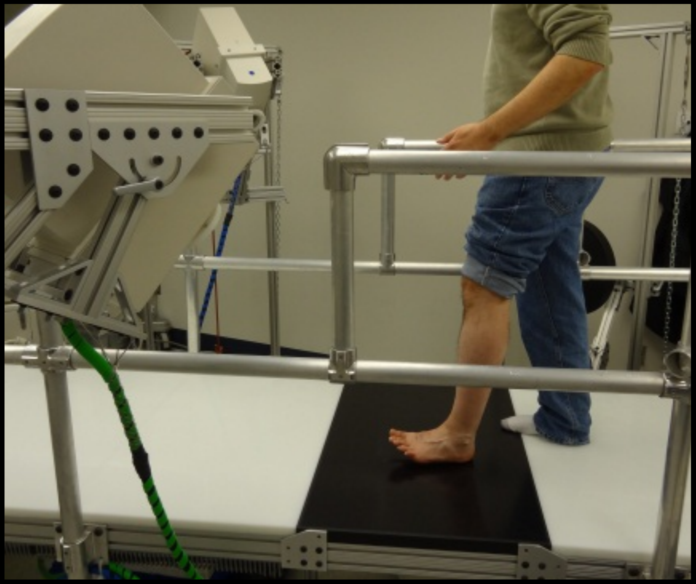


Final floor

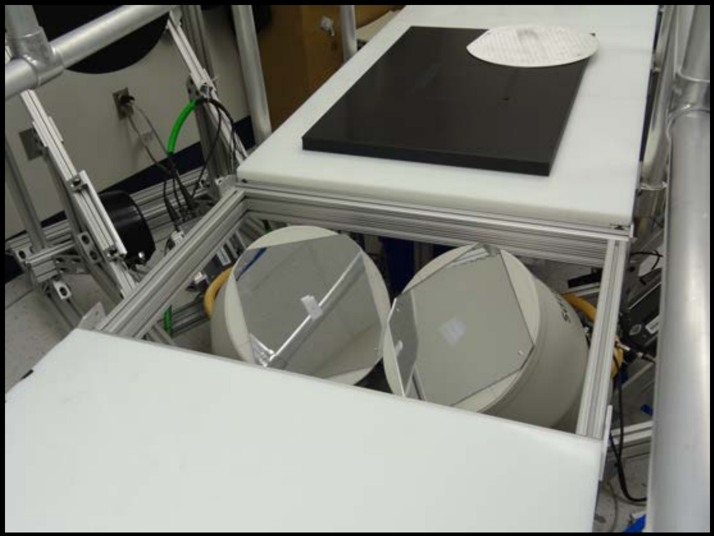






Light sabers?

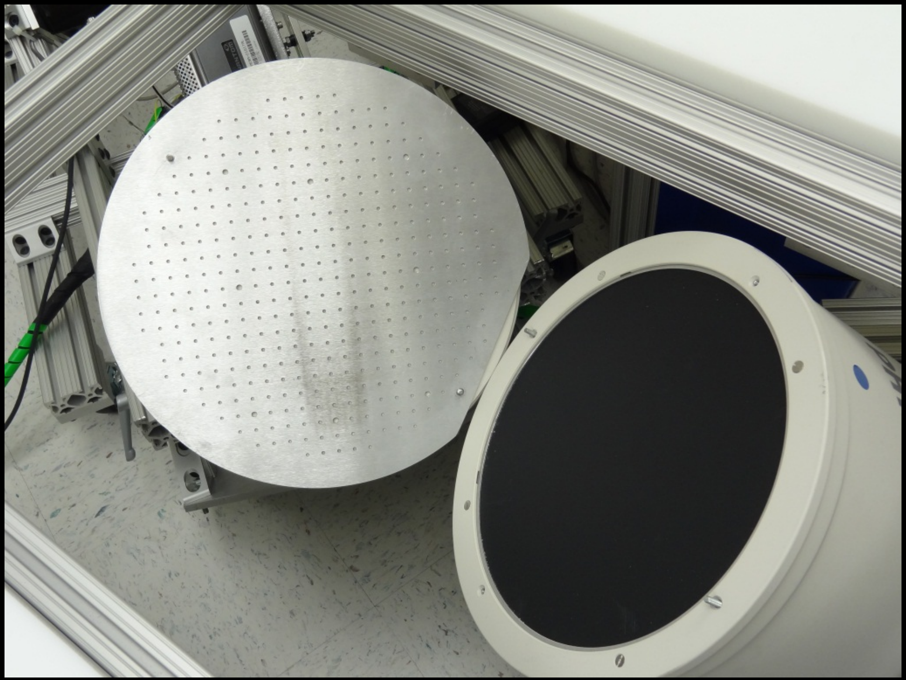
Laser alignment

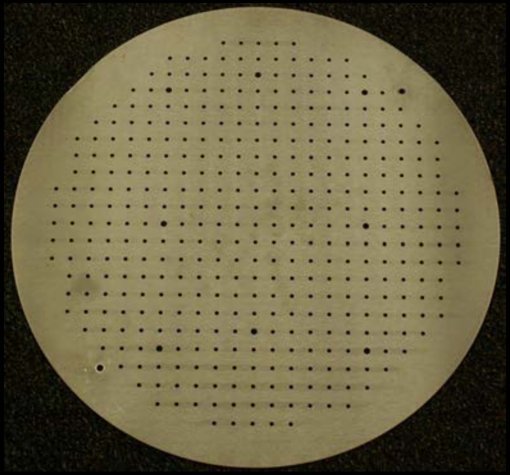


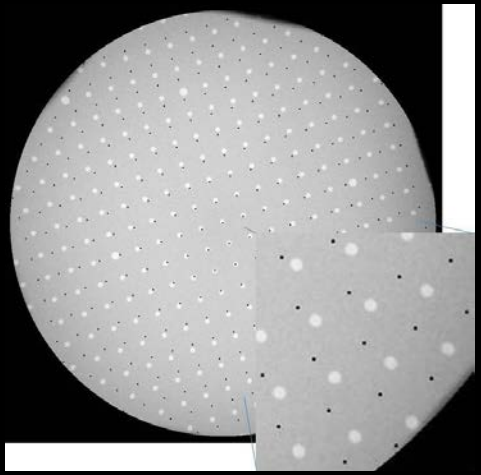
Customized software

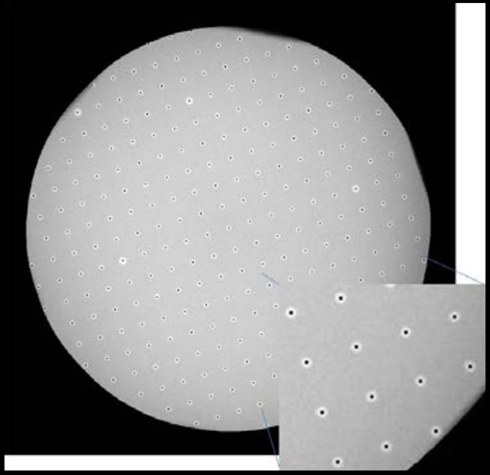
- Matlab, C/C++, CUDA
- Phase I: distortion and bias correction, 3D calibration
- Phase II: generation of digital reconstructed radiographs (DRRs)
- Phase III: implementation of similarity measures and comparison methods
- Phase IV: speed and memory optimization

Distortion correction

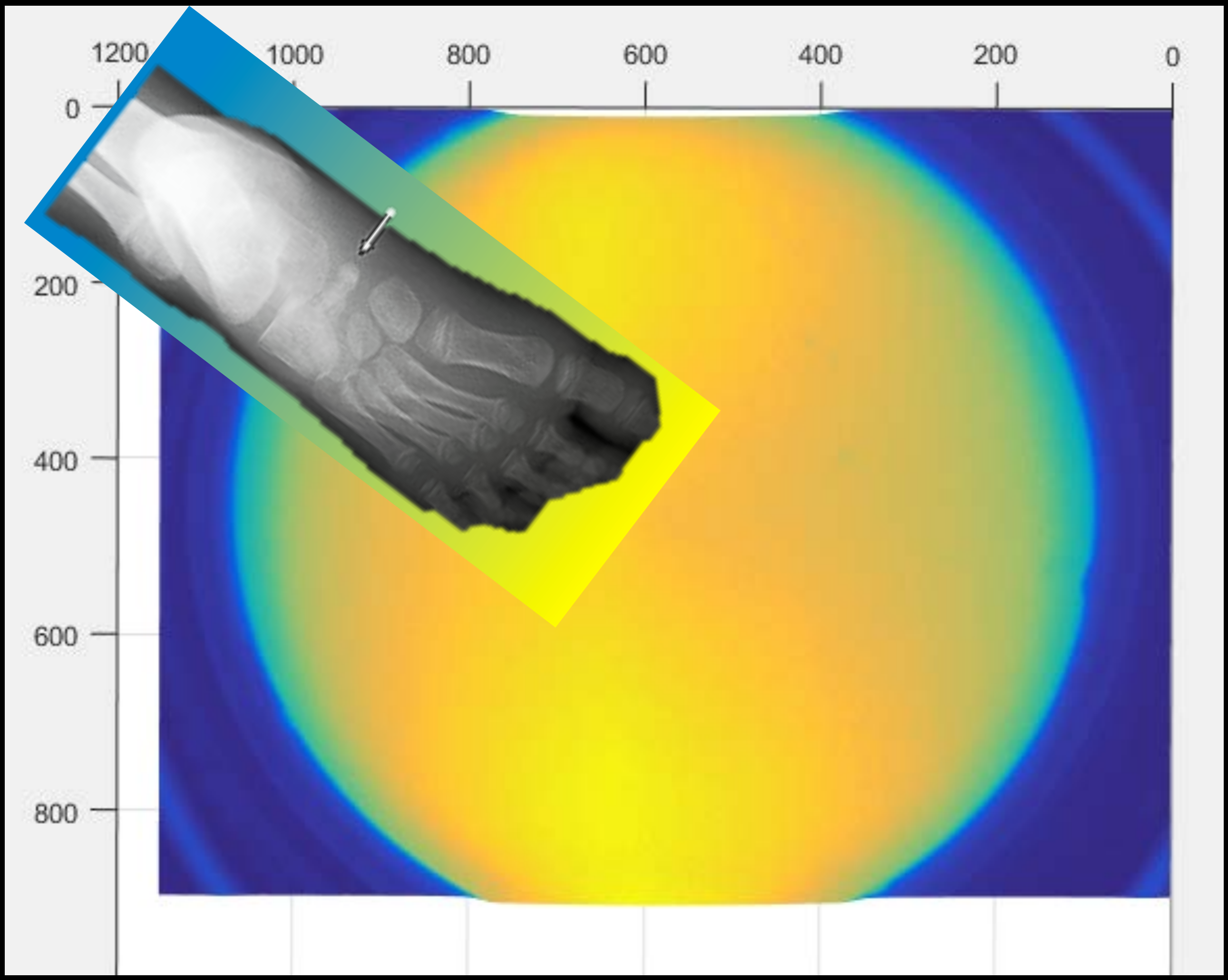




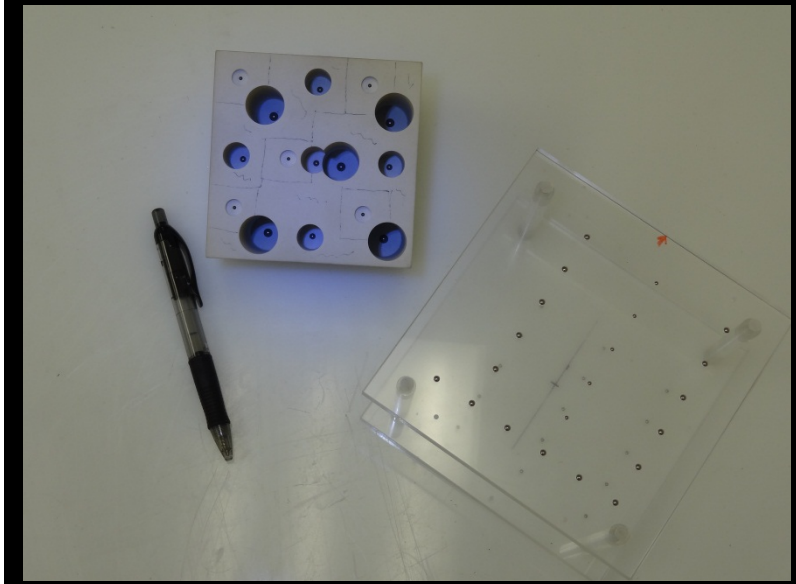


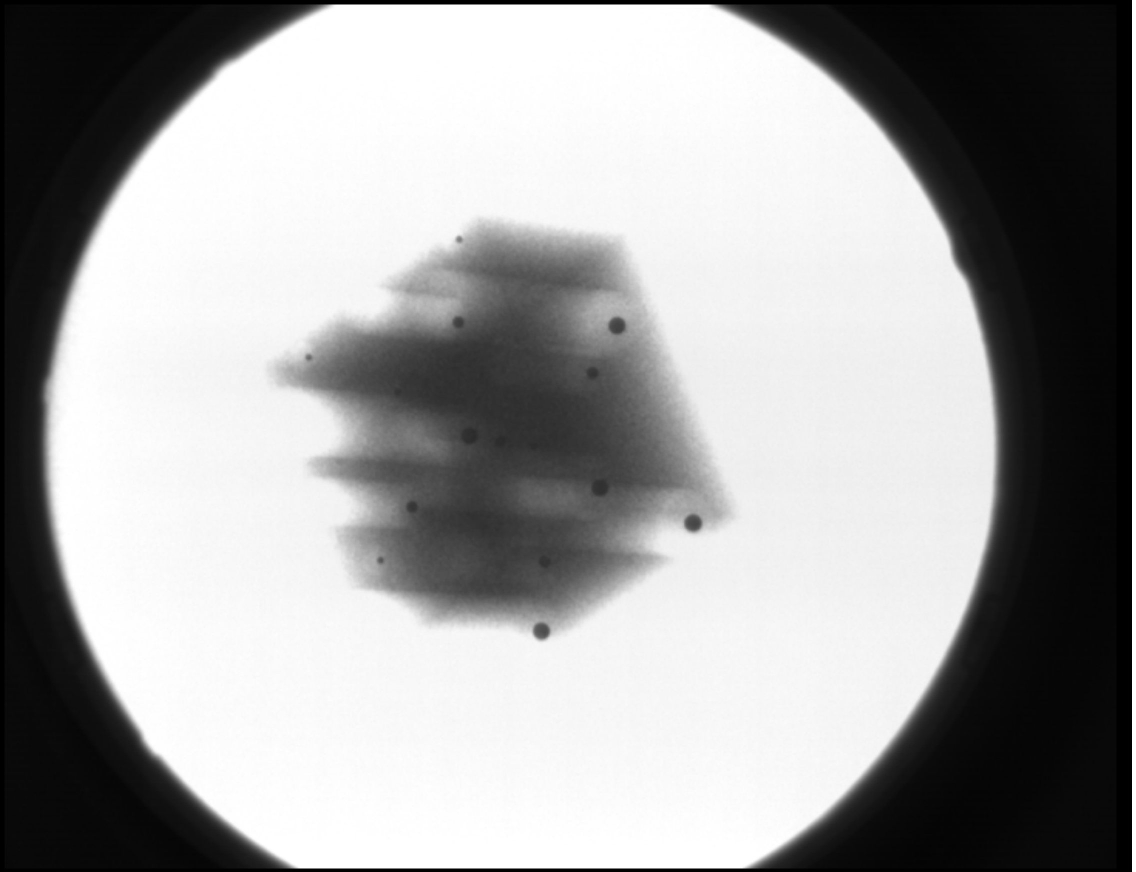


Flat-field correction

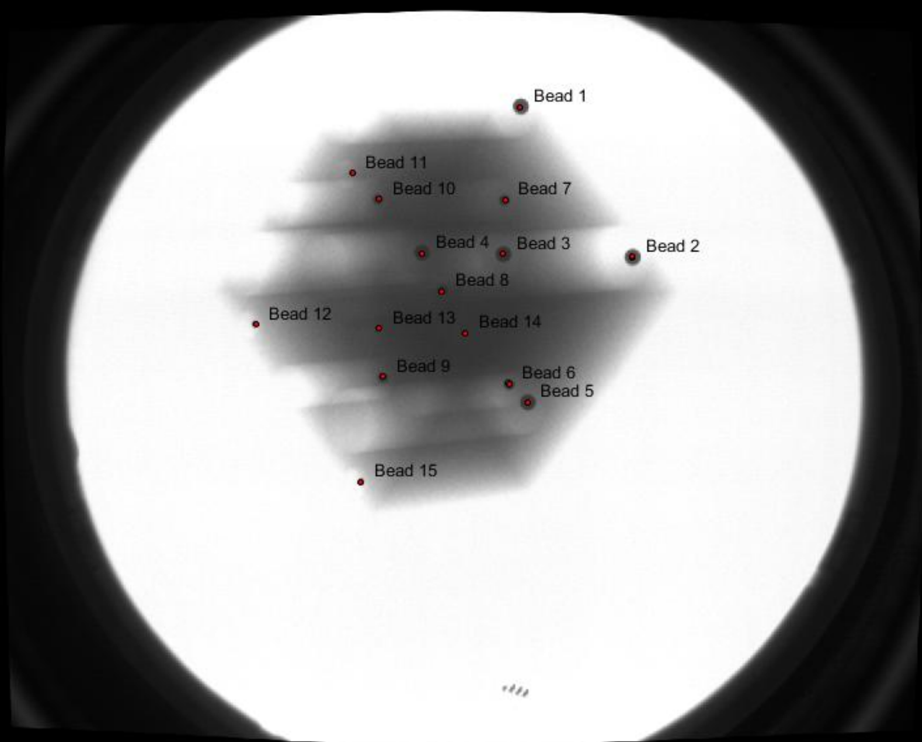


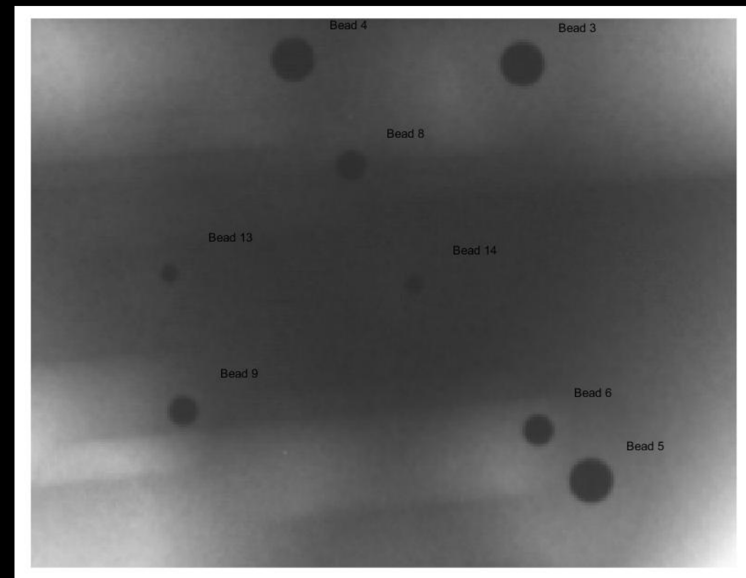
3D Calibration

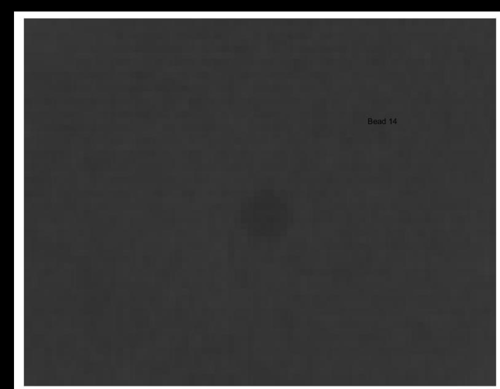




3D calibration revised

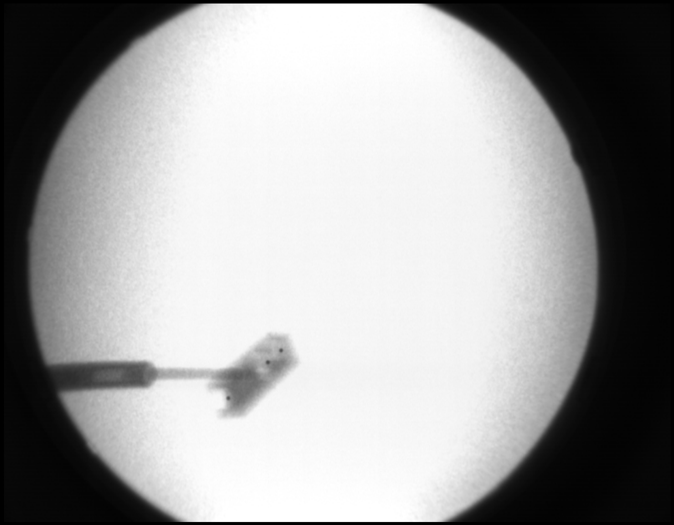




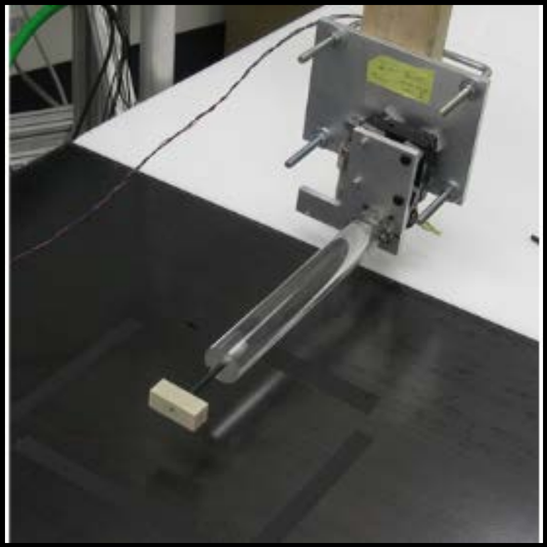


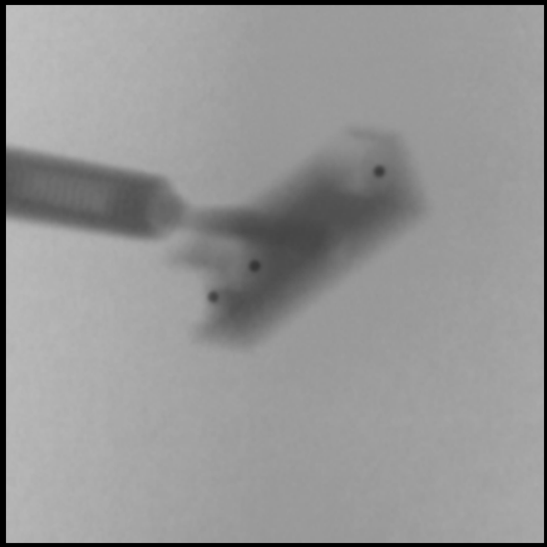
Validation: Bead-based

- Machined block or “wand”
  - 1.6mm tantalum beads
  - measured within 7 microns
- Wand translated and rotated via a 1 micron precision stepper-motor (static testing)
- Wand manually waved though FOV at ~0.5m/s (dynamic testing)



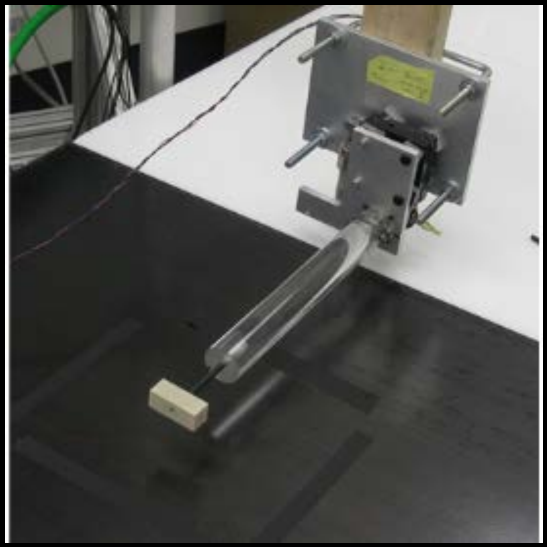
Validation: Bead-based, Static

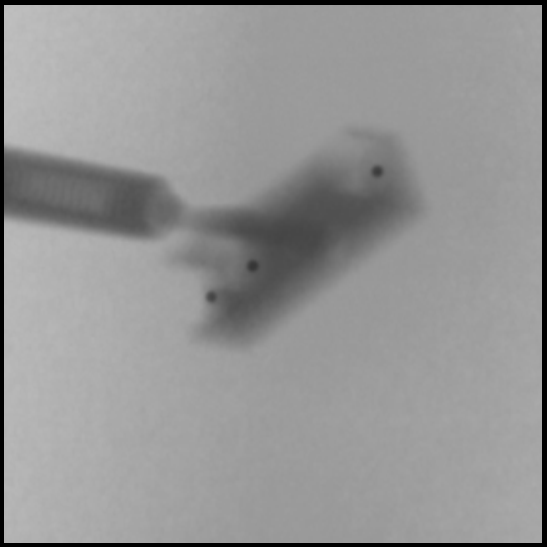




- Average translational accuracy = 0.0811 mm
- Average translational precision = ± 0.0103 mm
- Average rotational accuracy = 0.1541°
- Average rotation precision = ± 0.1382 °

Validation: Bead-based, Dynamic



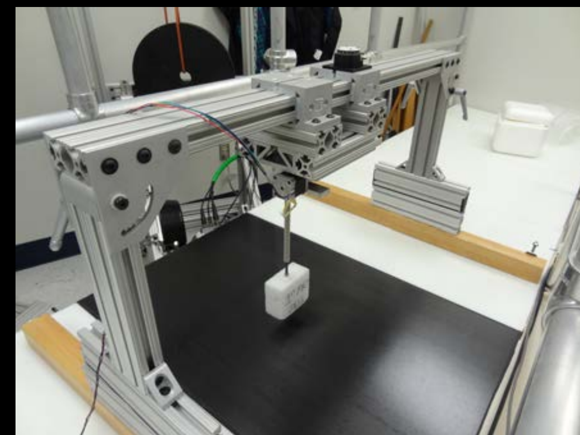


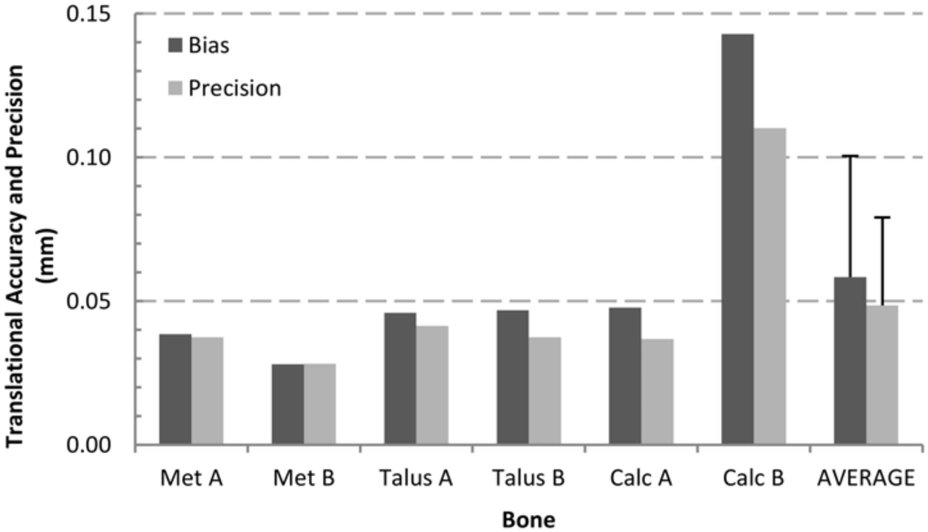
- Average accuracy = 0.1260 mm
- Average precision = ± 0.1218 mm

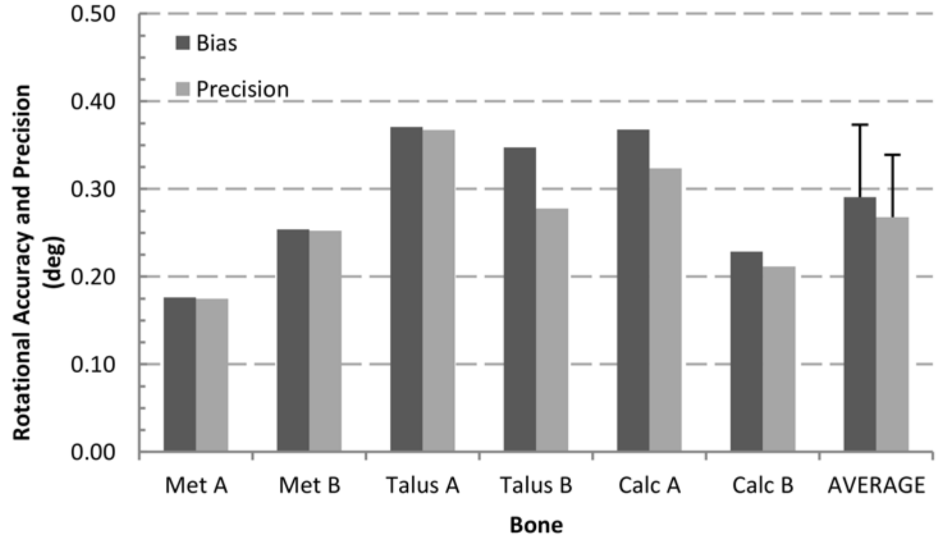
Validation: Bone-based

- Bones in foam block
  - 1.6mm tantalum beads
- Block translated and rotated via a 1 micron precision ng)
- Block ma at ~1 m/s (dynamic

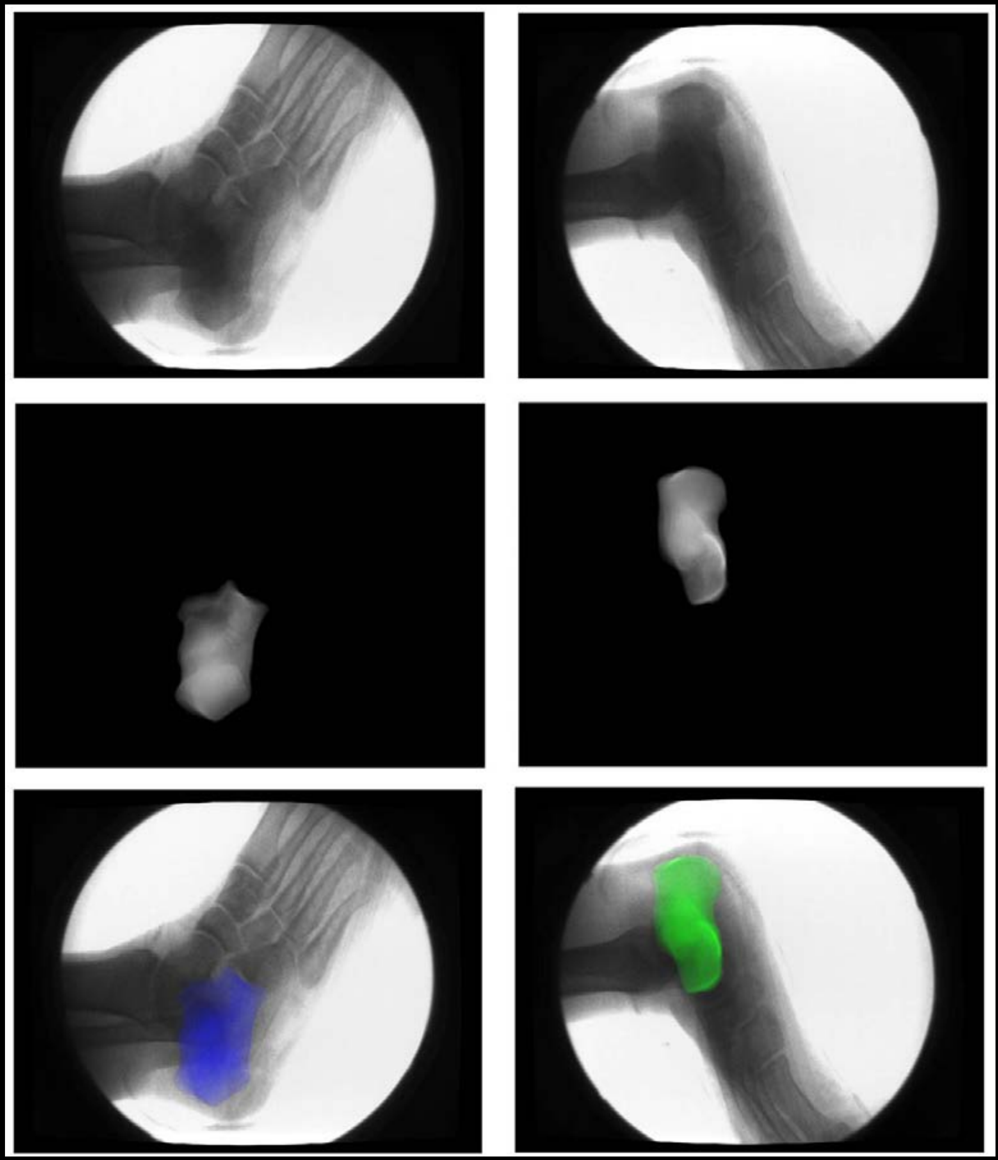
Validation: Bone-based, Static



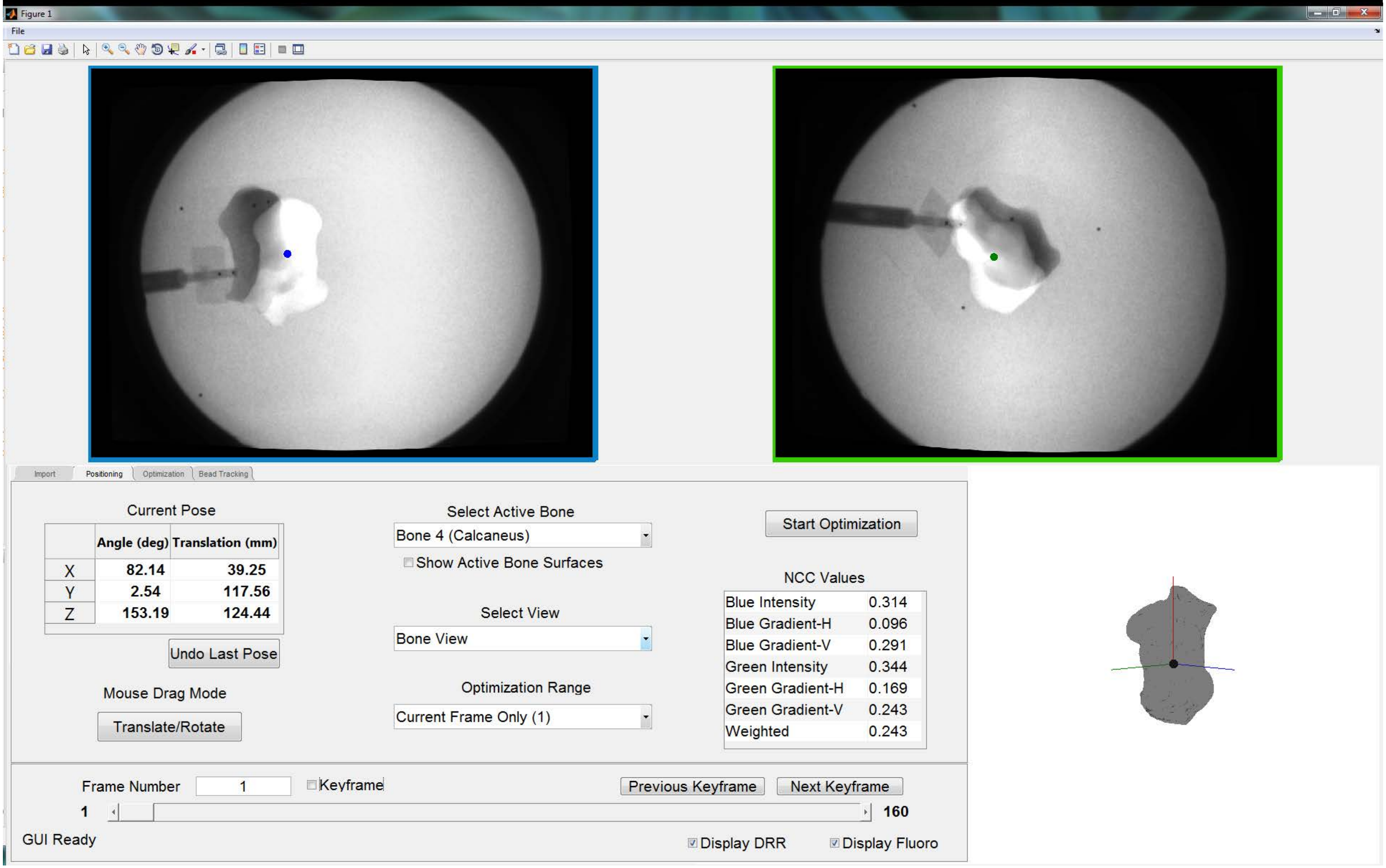




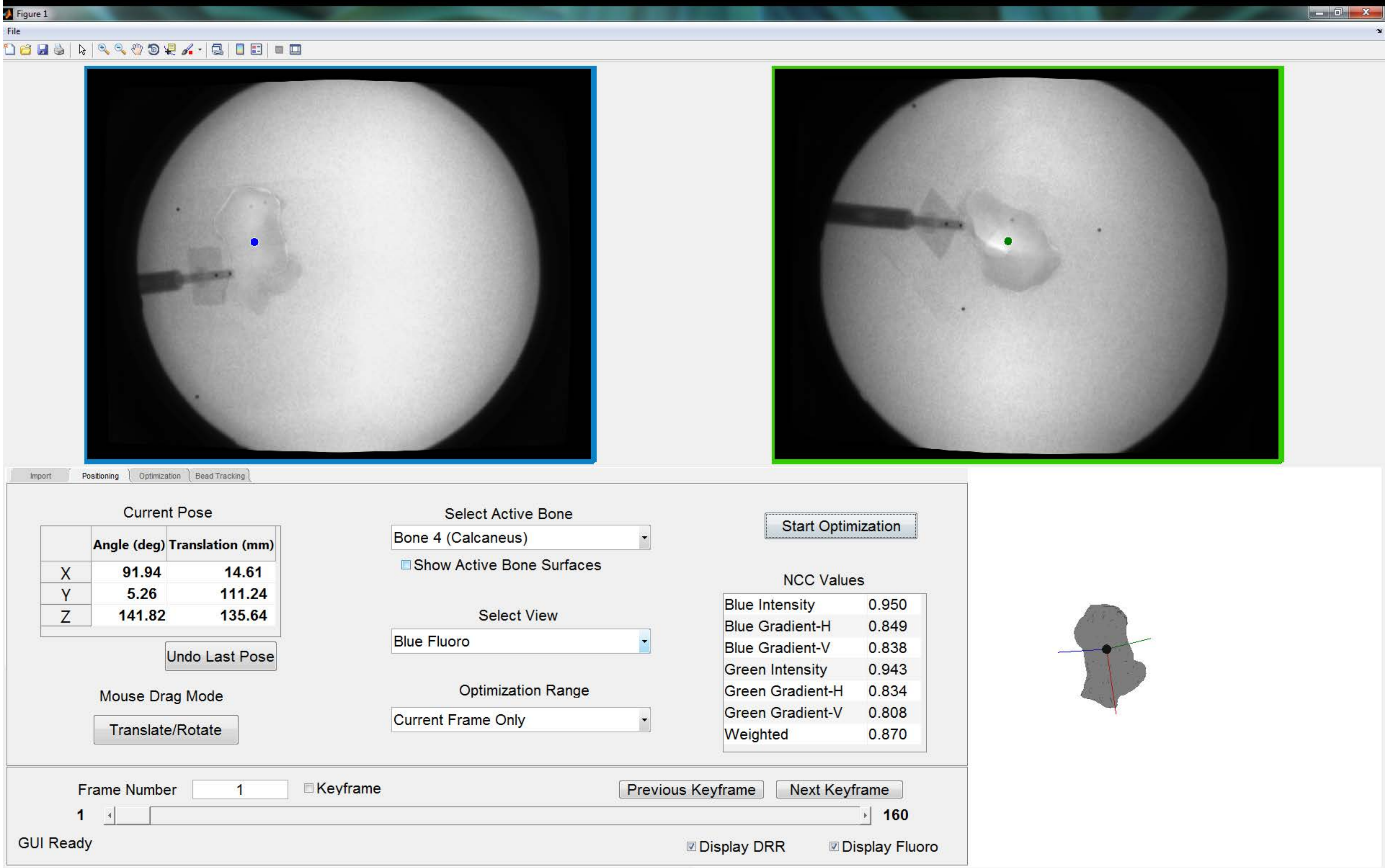
Sample DRR



GUI: unoptimized



GUI: optimized



Sample videos