Percutaneous Spinal Injections – problem presentation for HW1

Gabor Fichtinger, PhD

Director of Engineering,

Associate Research Professor of Computer Science and Radiology

NSF-Funded Engineering Research Center for Computer-Integrated Surgical Systems and Technology

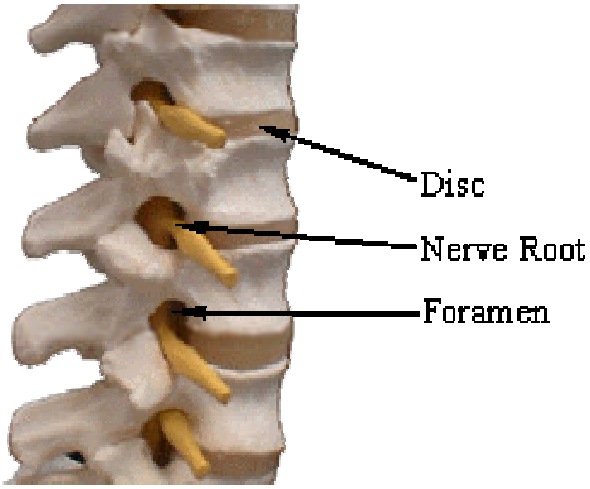
Why Needles?

- **Potentially significant impact on medical practice**
  - **Minimally invasive (compared to open surgery)**
    - Faster recovery
    - Less morbidity
    - Fewer complications
    - Lower cost
    - Repeatable in many indications
  - **Sharply increasing number of procedures**

- **Challenging but doable**
  - ***Constrained process – formally describable***
  - **Major challenges (in addition to open/lap surgery):**
    - **no visibility**
    - **no access**
    - **no room to maneuver**
    - **no room to recover**

Why Spine? Why pain management?

- In US alone 70% of population affected in lifetime
- Single most expensive disease
- Pain management: alleviate pain caused by stressed/pressured/pinched spinal nerve by suppressing sensory input at nerve root
- Numb with lidocaine/novocaine etc.

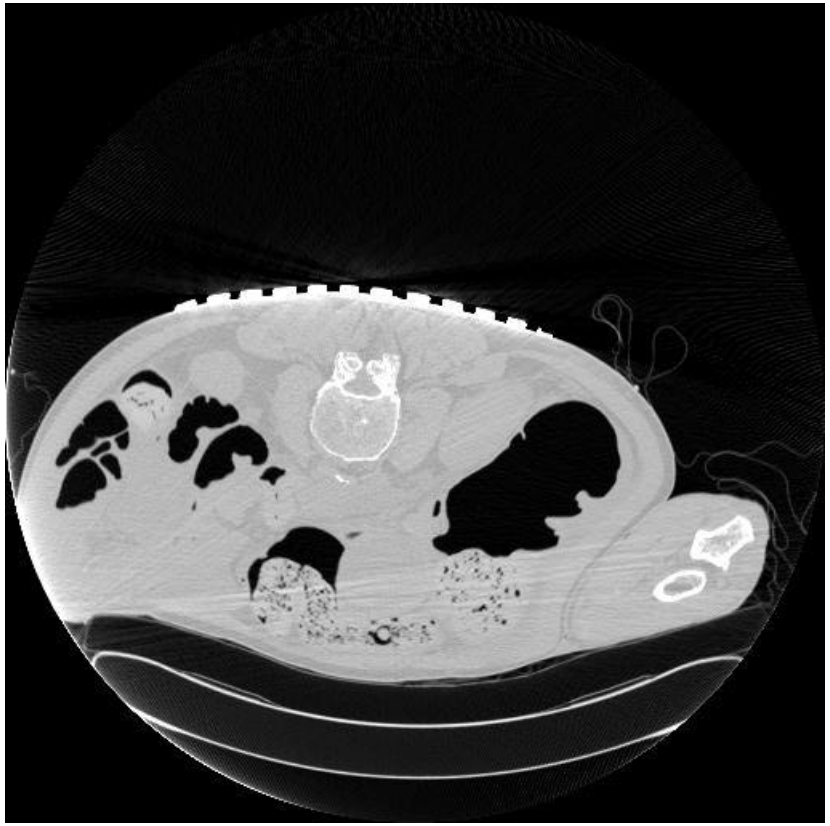


Key technical issues

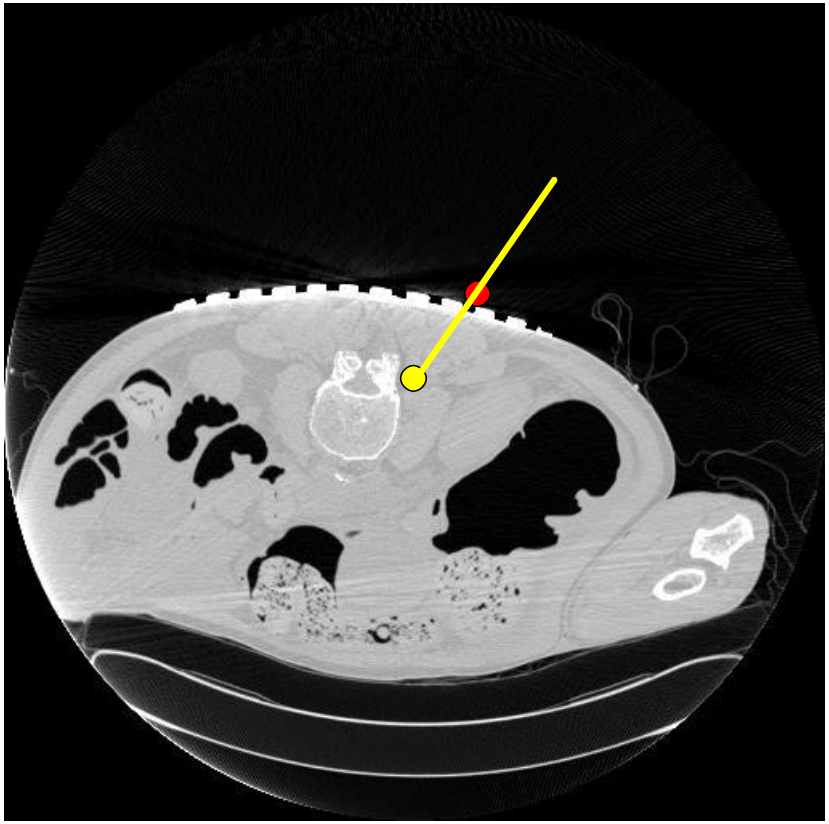
- Accuracy
  - Longevity of pain relief
  - Collateral damage
  - Pain during procedure
  - Acceptable ~ 1mm
- Time
  - Volume/throughput = money
  - Good surgeons < 10 min
  - Mediocre/poor surgeons ~ 30-40 min
- Toxic radiation – primarily to physician !!!
  - Good surgeons < total 5.0 sec beam time
  - Mediocre/poor surgeons ~ 30 sec beam time

Current standard 1: CT guidance

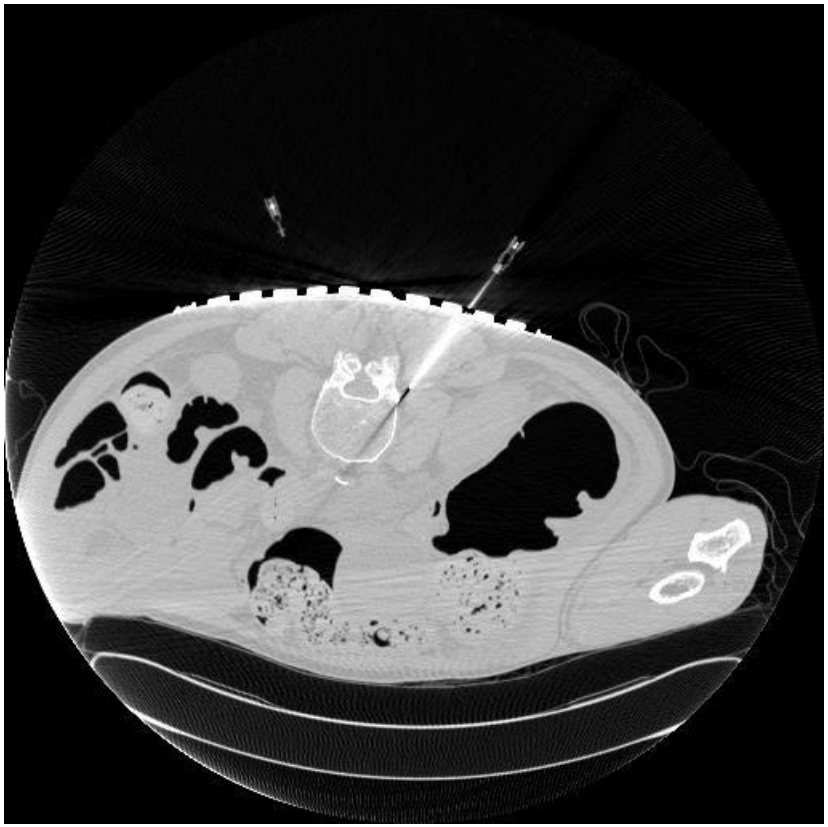
Affix IZI Biopsy Strip



Pick Entry and Target

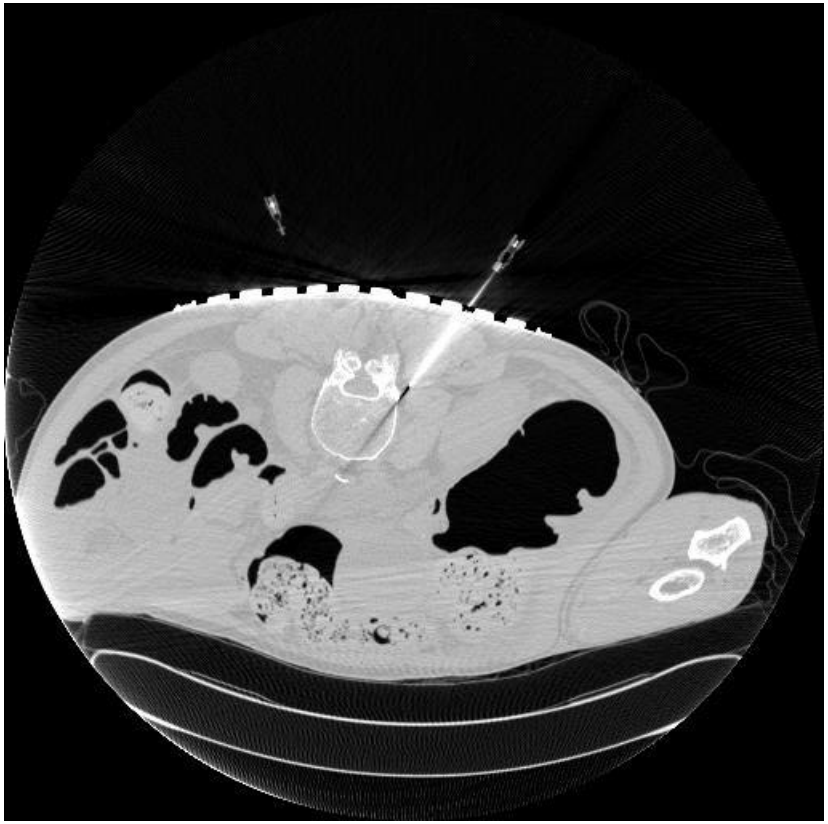


Current workflow for CT-guided procedure



1. Put patient in prone to scanner
2. Palpate vertebra
3. Affix IZI Biopsy Strip fiducials
4. Take thin volume scan
5. Select slice of interest
6. Pick target and entry
7. Determine angle and depth
8. Pull out patient to outer laser plane
9. Identify entry on skin
10. Touch needle to entry point
11. Enter needle manually – 22G beveled
12. Maintain insertion angle by sight
13. Keep needle in laser plane
14. Judge current insertion depth by feeling
15. *Insert contrast (optional)*
16. Push patient back to scan plane
17. Take confirmation CT
18. Pull out patient
19. Inject therapeutic agent

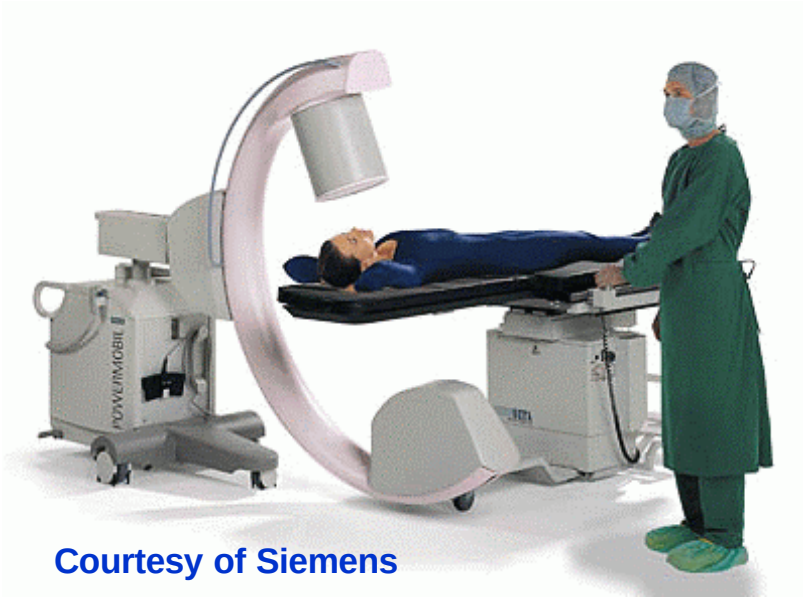
The challenge



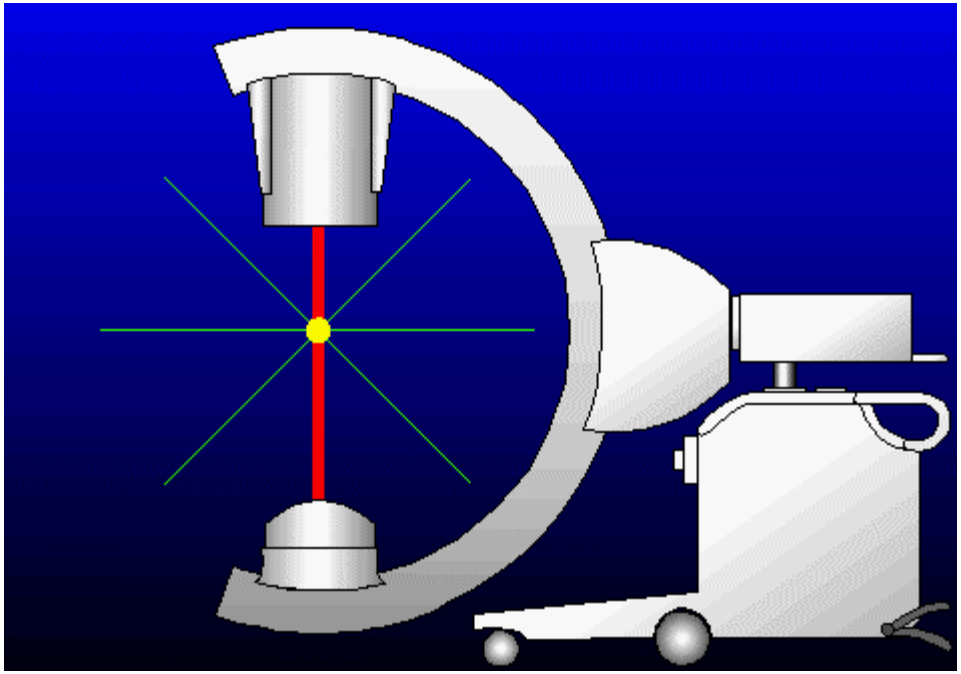
- Transfer entry, angle and depth over patient
- Control all 3-DOF simultaneously during insertion

Current standard 2: C-arm Fluoroscopy

- Mobile
- Real-time
- Inexpensive
- Broad coverage

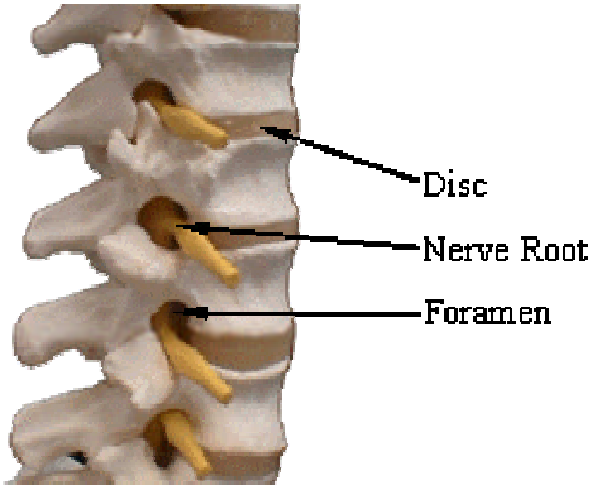


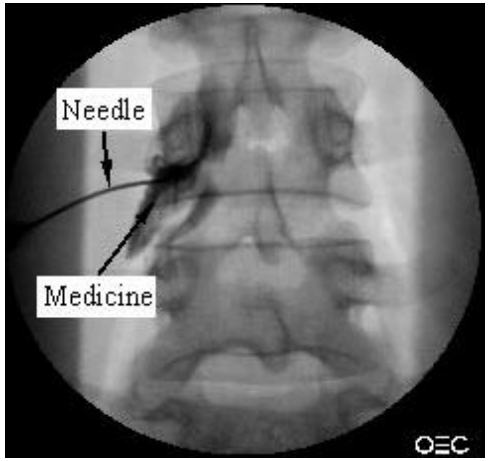
Courtesy of Siemens



- Limited rotation
- X-ray dose
- Low soft tissue contract
- Need for calibration
- Need for tracking

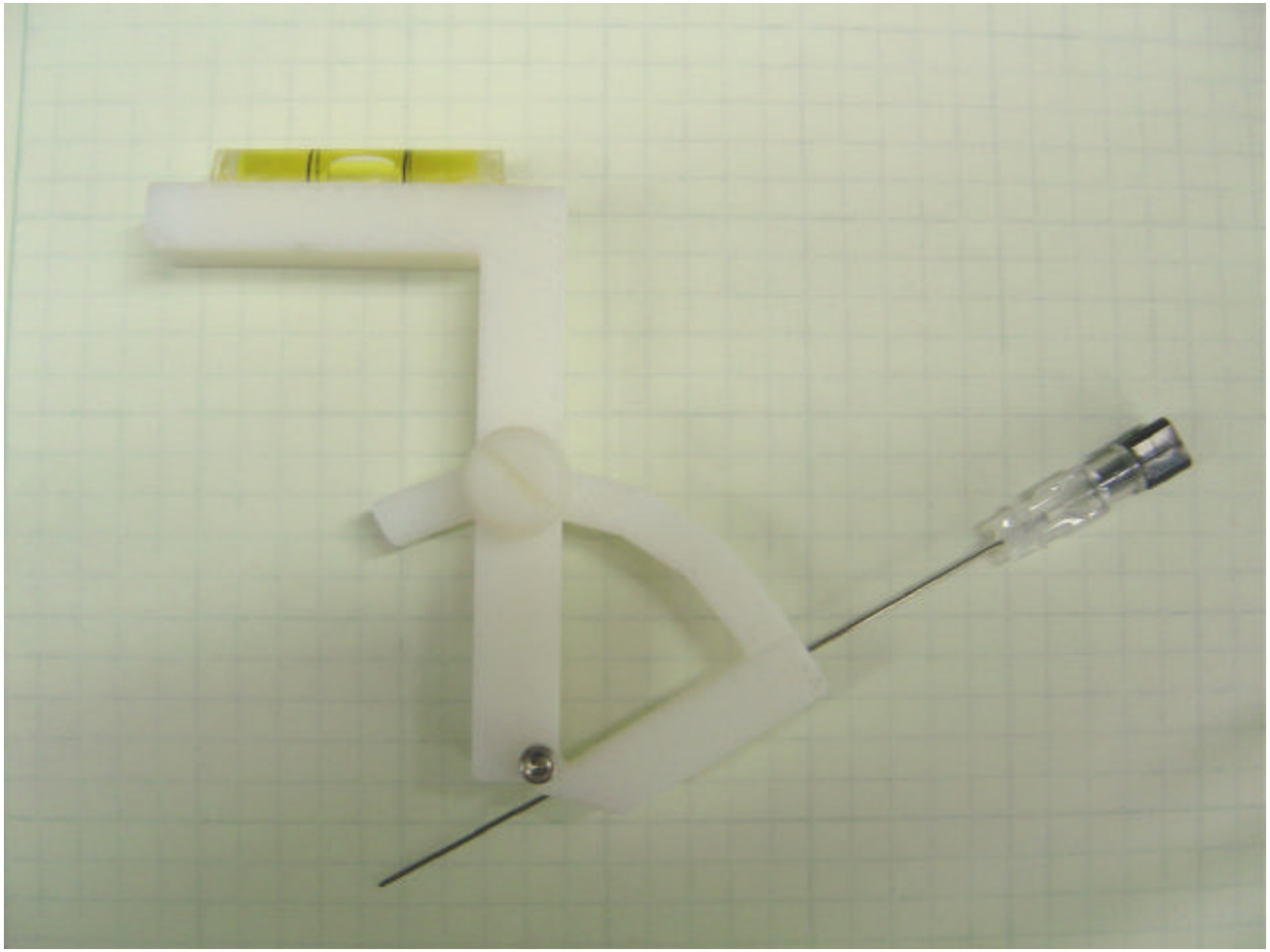
Current workflow for Fluoro-guided procedure





1. Put patient in prone on table
2. Palpate vertebra
3. Set C-arm in anticipated needle direction
4. Turn on beam
5. Adjust C-arm angle to optimal
6. Reach into beam with needle
7. Touch entry with needle tip
8. Keep needle perpendicular to beam
9. Optimize entry location
10. Fulcrum with needle till barrel-view
11. Turn off the beam
12. Rotate C-arm by 90 degrees
13. Turn beam on, keep beam on
14. Insert needle – 22G beveled
15. Monitor insertion depth/deflection in image
16. Stop needle at target position
17. *Insert contrast (optional)*
18. Take confirmation C-arm image
19. Inject therapeutic agent

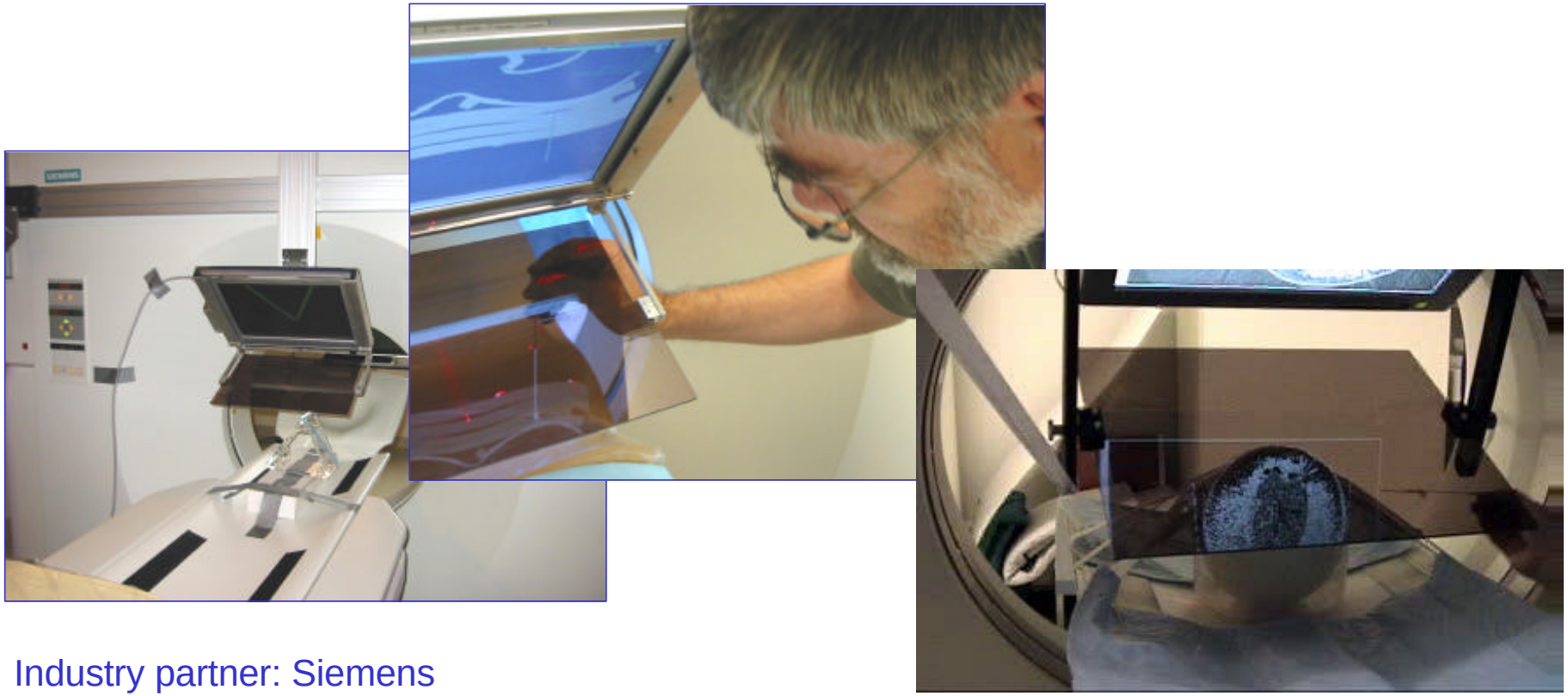
Handheld Needle Guide



CT-Mounted Laser Guide

CT-Mounted Image Overlay

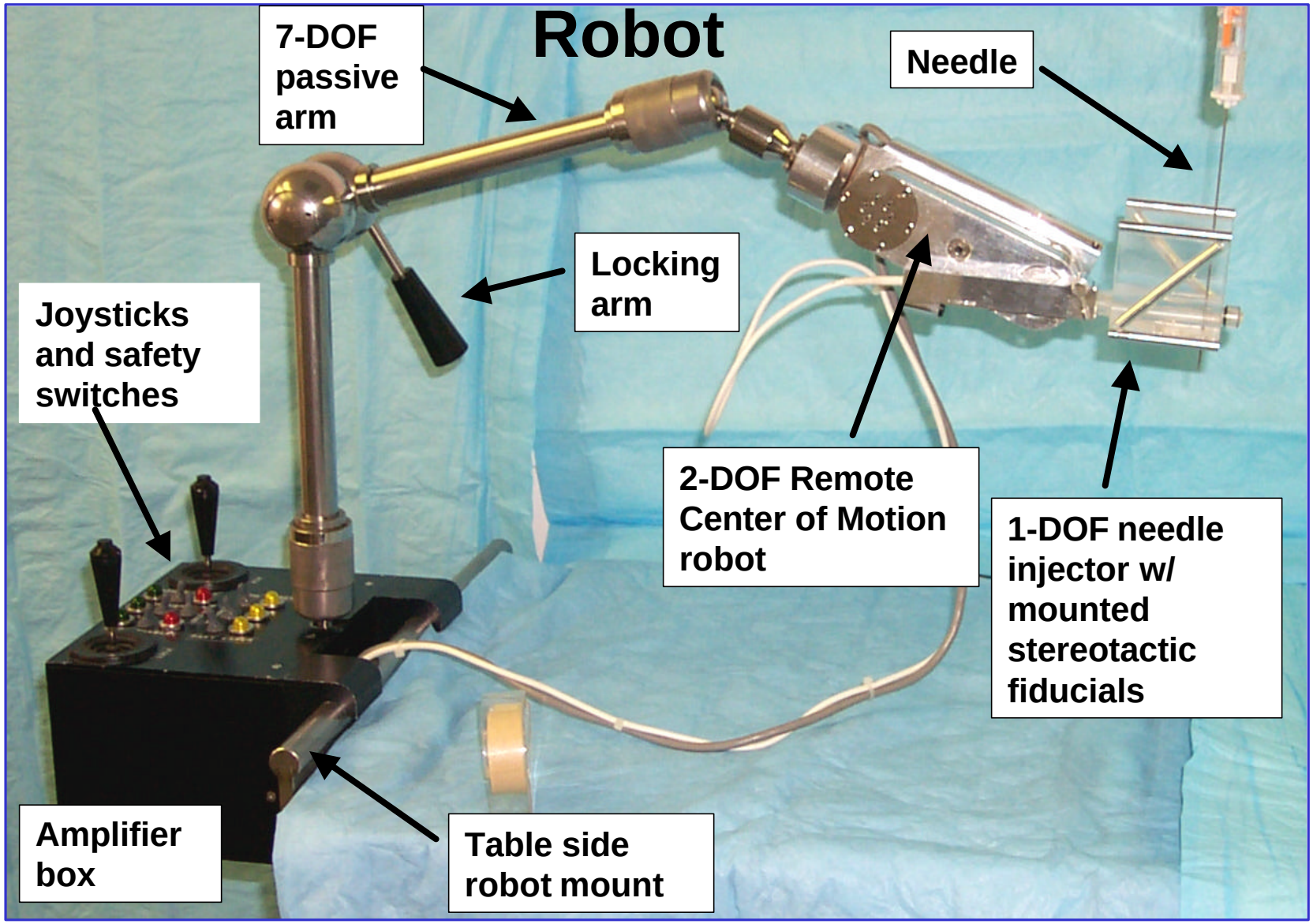
Goal	: Simple and radiation-free X-ray vision during surgery
Approach	: Merging data model with physical space through half-mirror
Future work	: Cadaver studies in June/July 2003



Industry partner: Siemens

Funded by Siemens, PI: Fichtinger

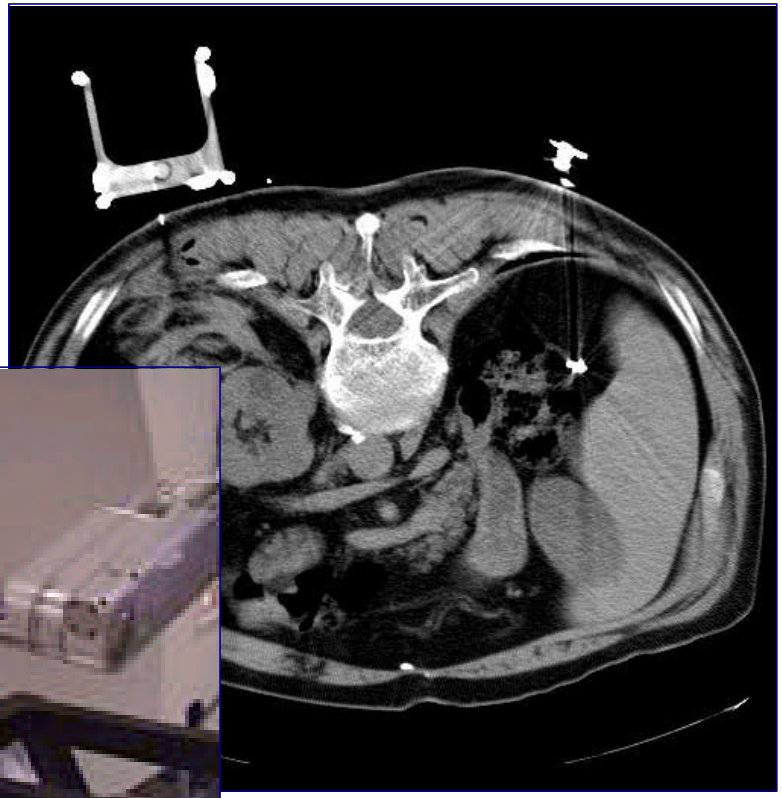
Robot assistance: 3-DOF RCM-PAKY



Robot: D. Stoianovici

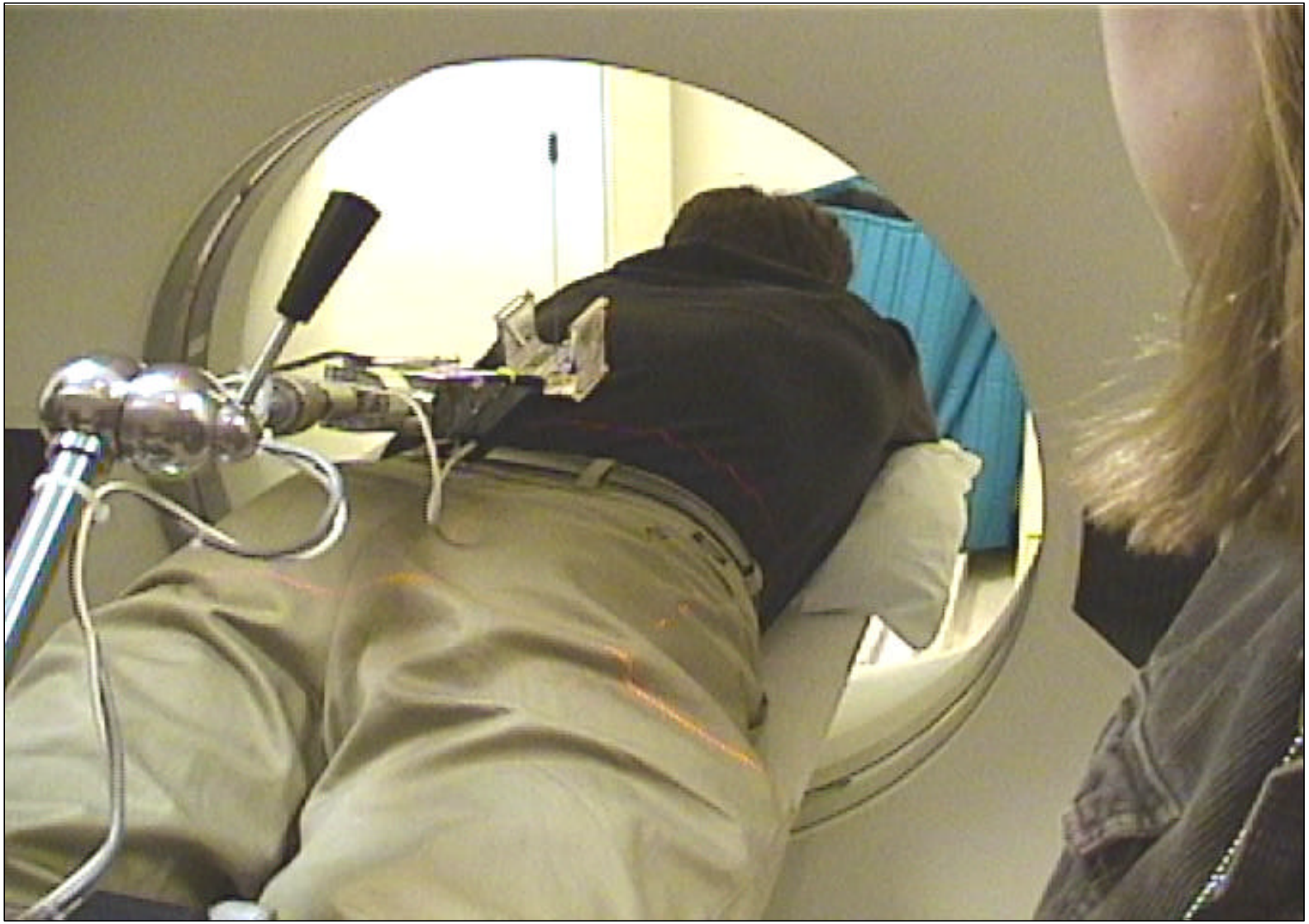
Robot-CT Registration: Stereotactic Adapter

Robot registered to CT from a single image using stereotactic frame on the end-effector

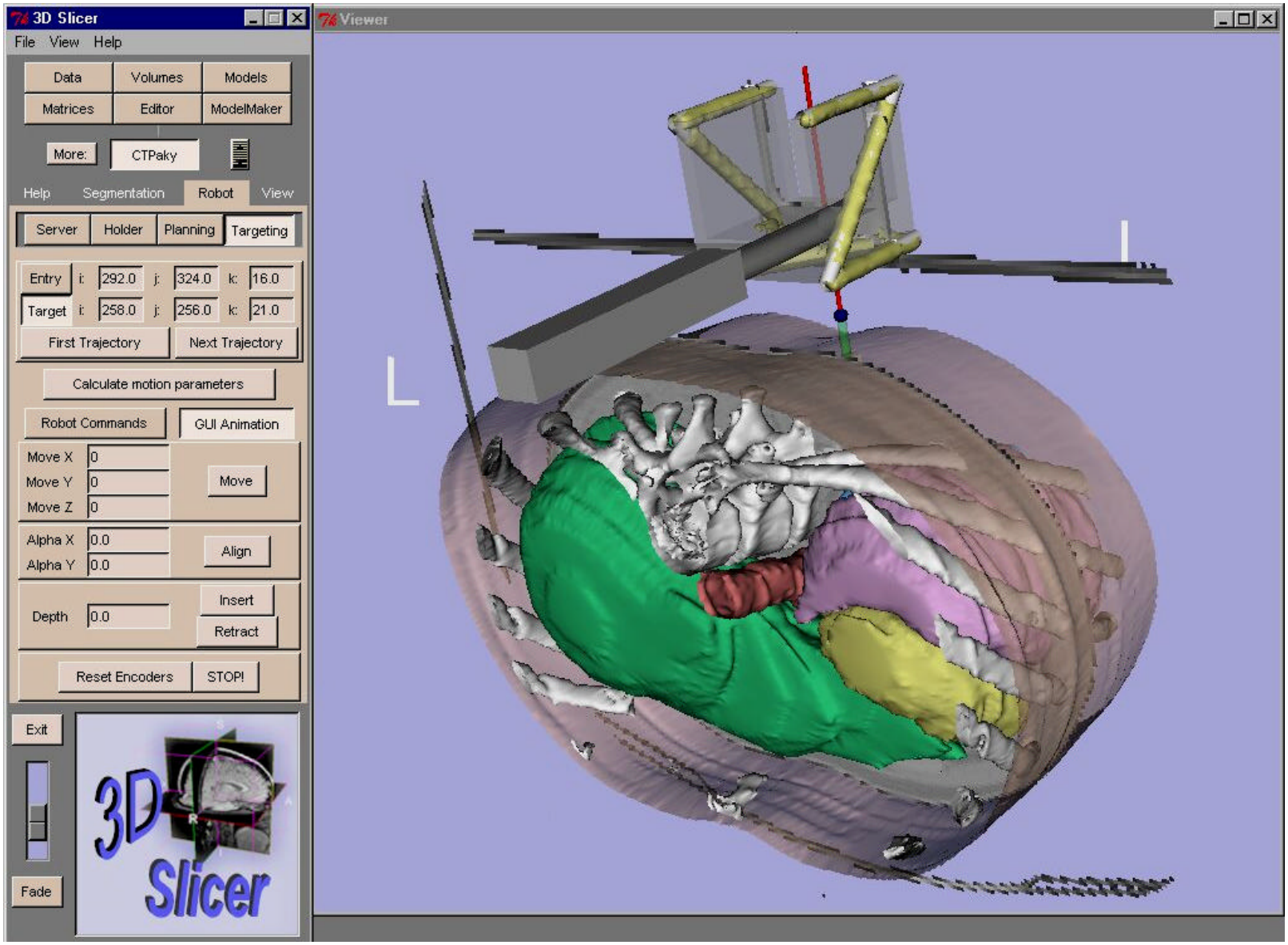


Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon (JHU Bayview)

CT-Robot Registration: Stereotactic Adapter

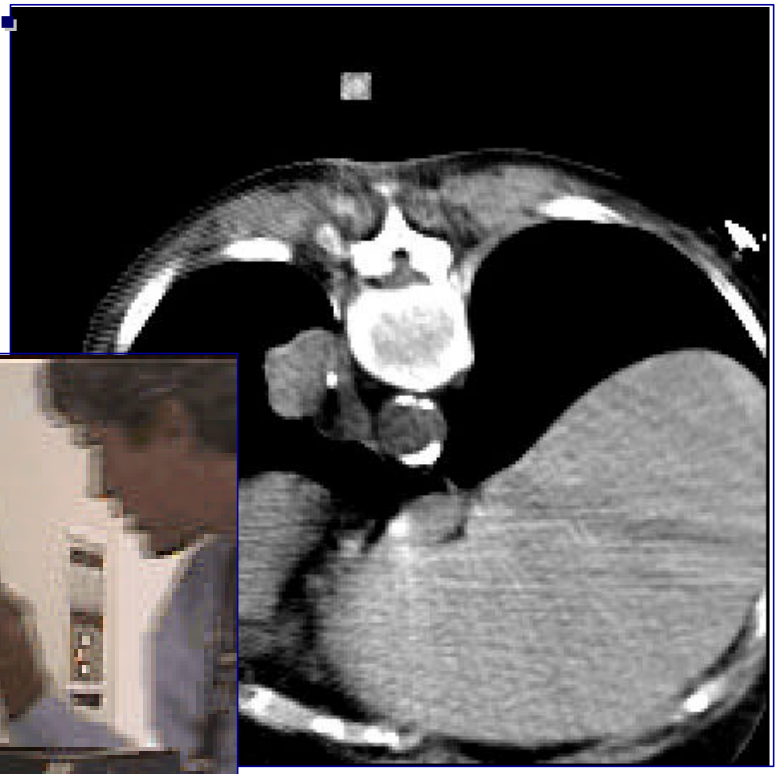


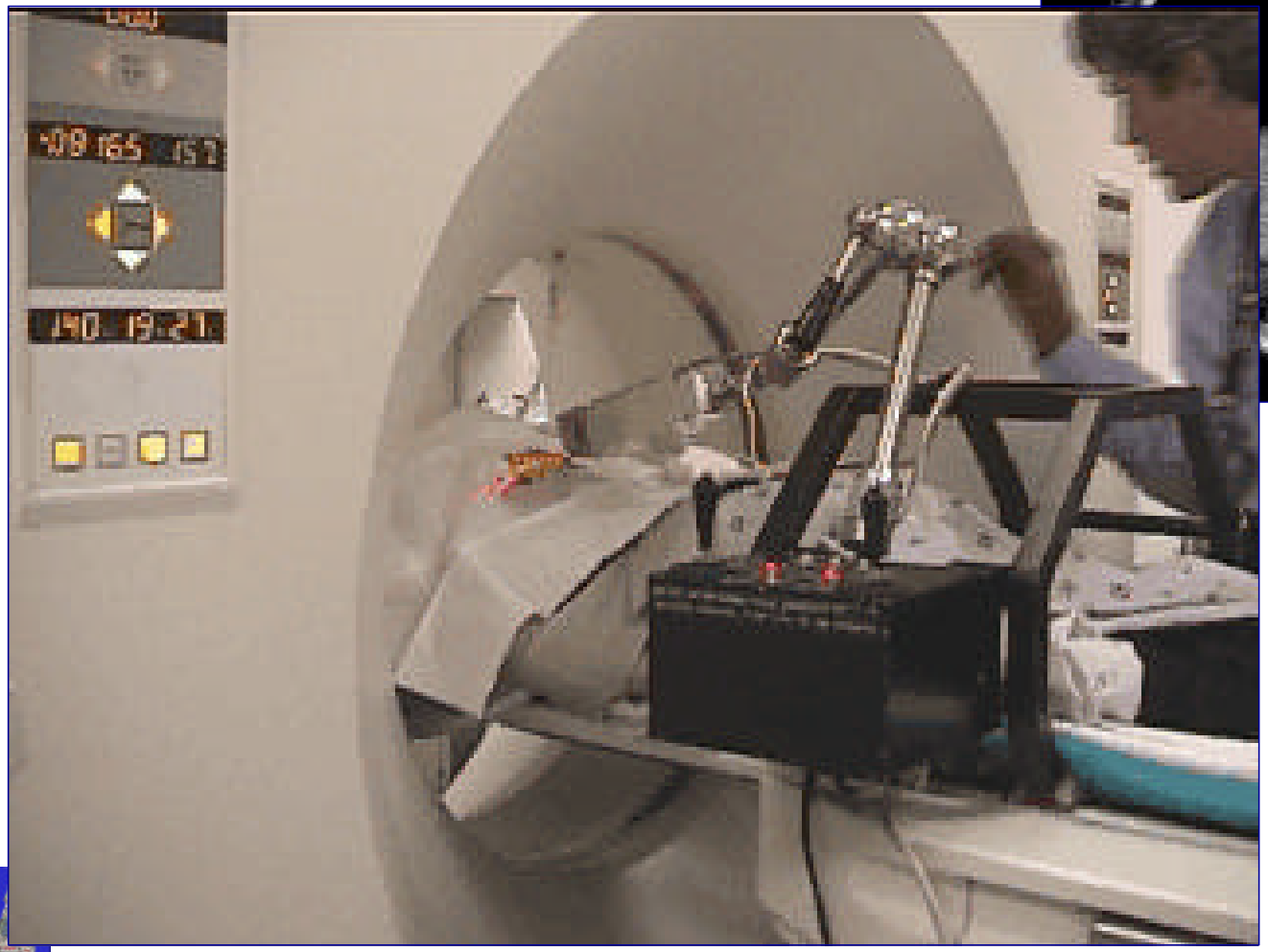
Surgical planning…



Robot-CT Registration: Scanner's Laser

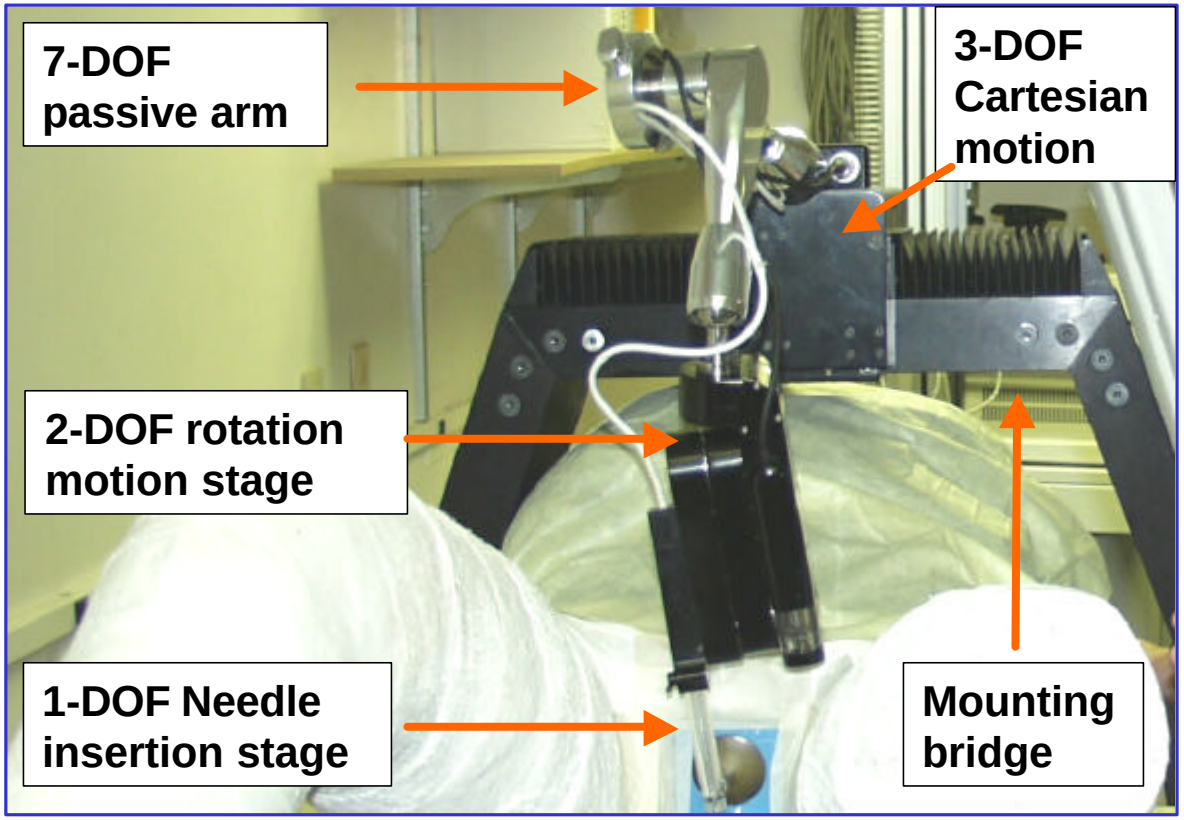
Robot registered to CT using the scanner's alignment laser





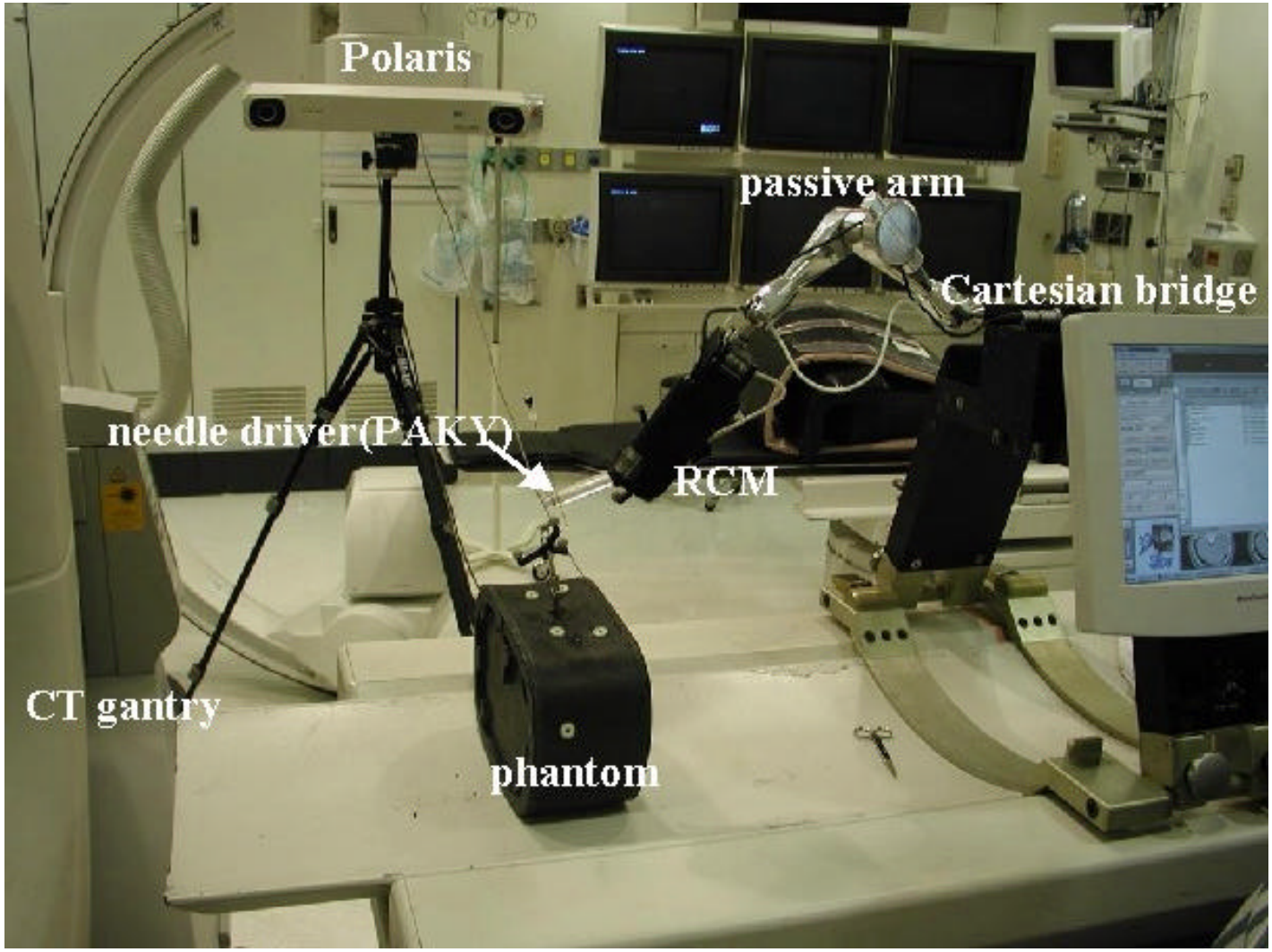
Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon, JHU Bayview and G. Fichtinger, ERC

The URobotics 6-DOF Accubot™ robot

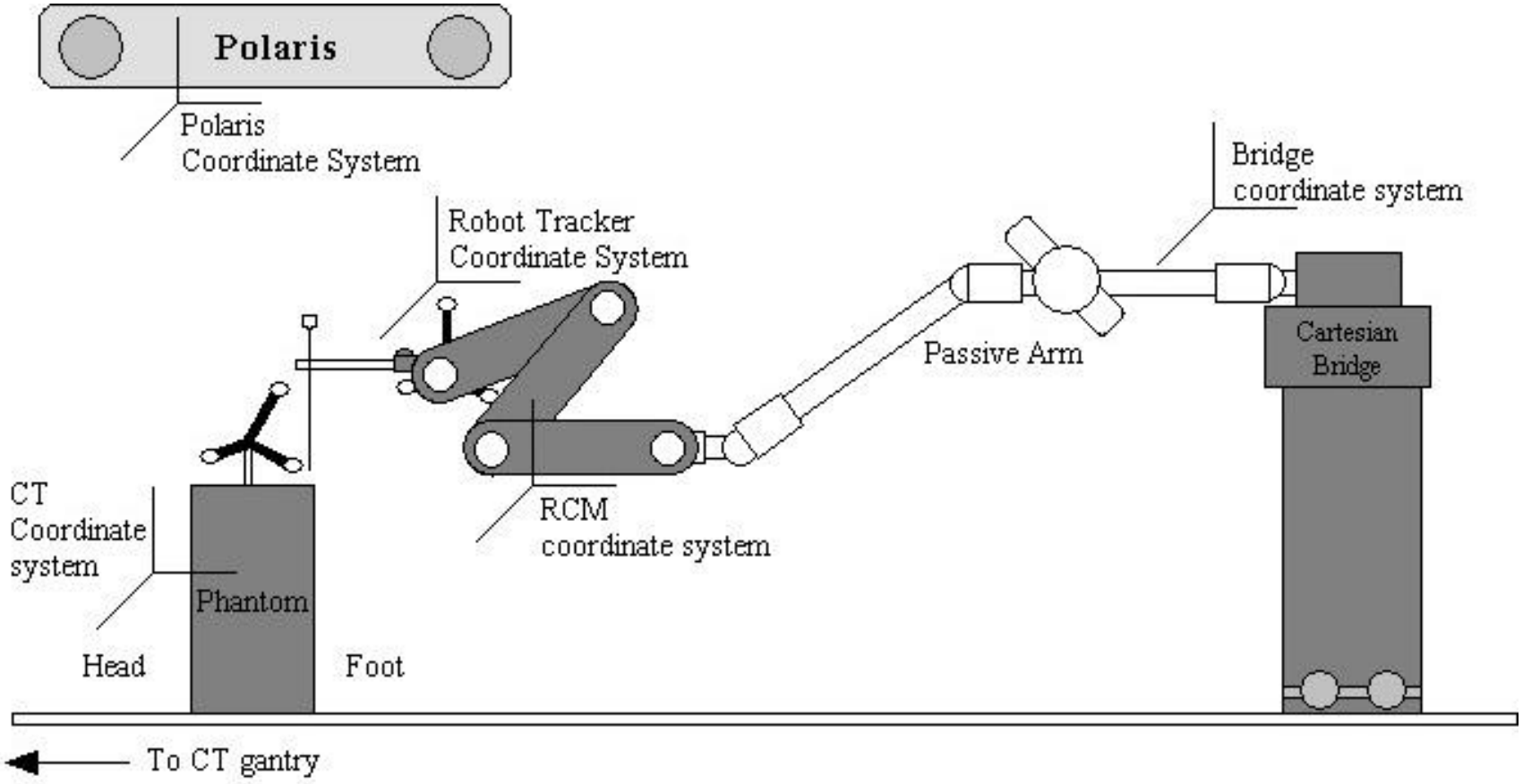


Robot: D. Stoianovici

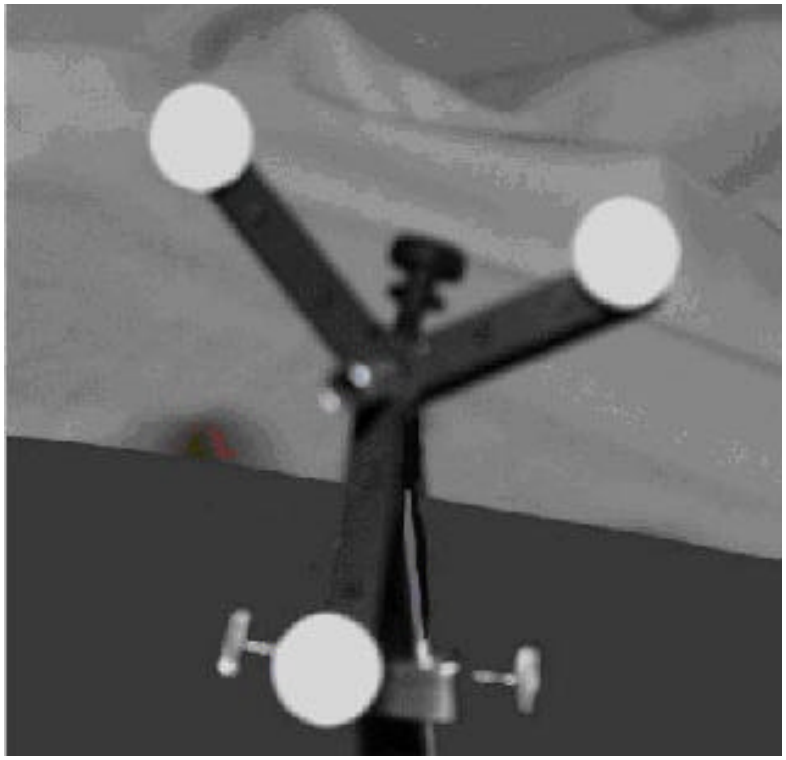
Robot-CT Registration: Optical Tracking



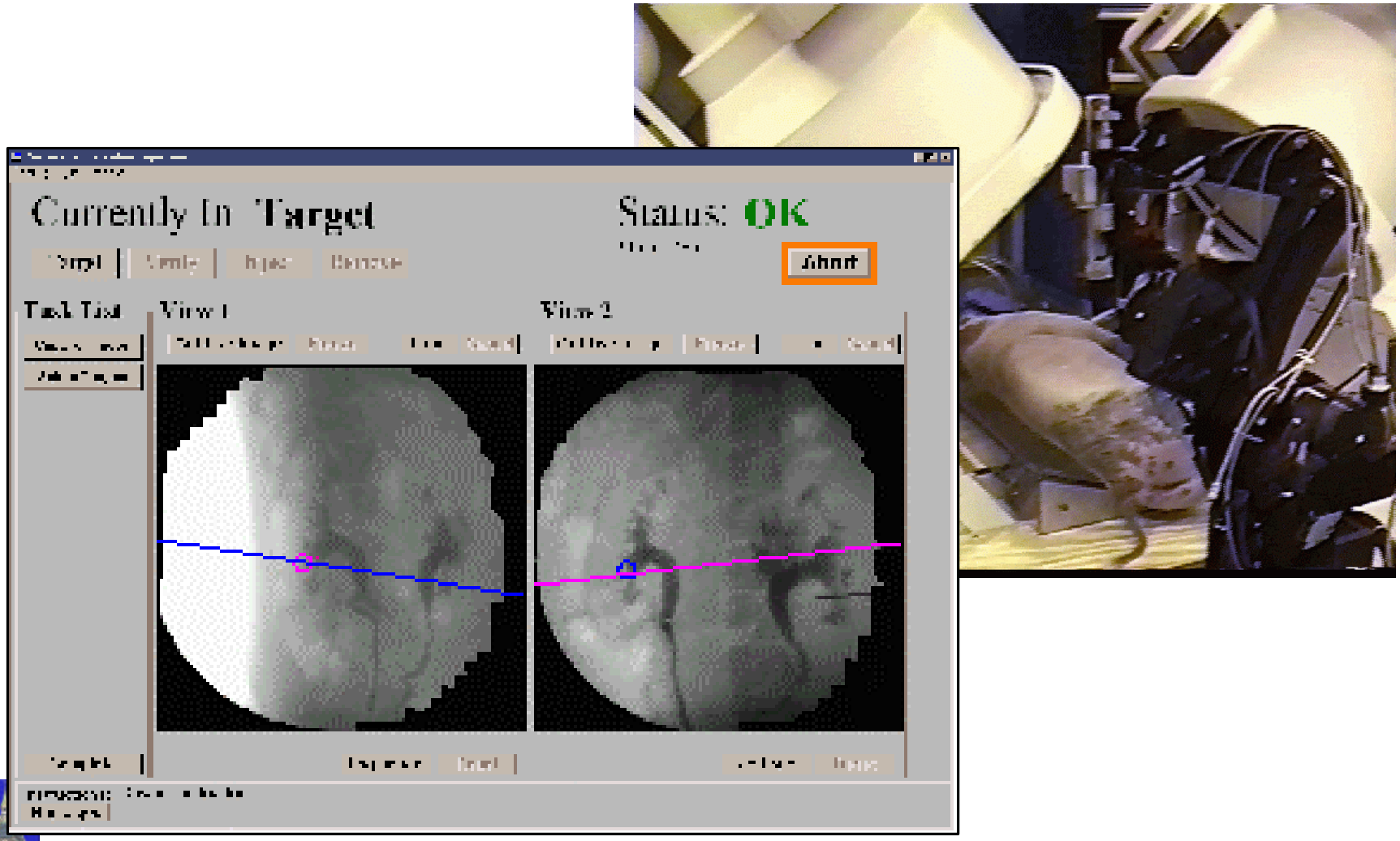
Robot-CT Registration: Optical Tracking



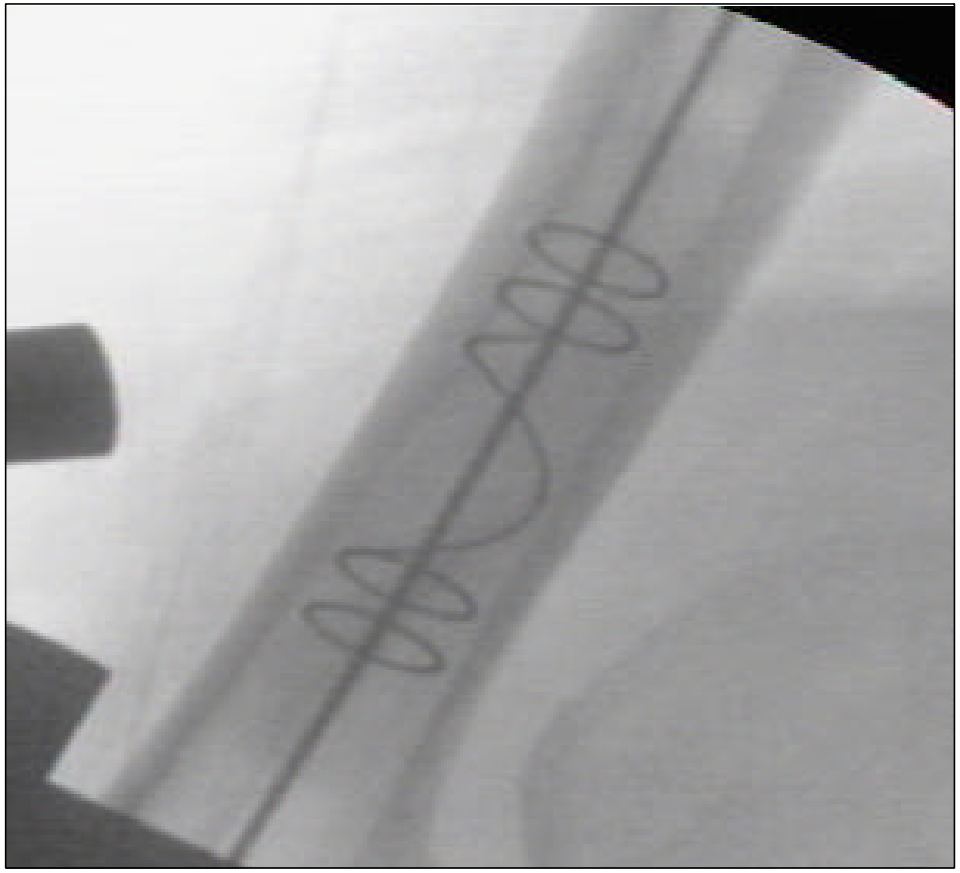
Robot-CT Registration: Fiducial carrier attached to spinous process



Robot-C-arm registration: Simple fiducial-based registration in biplane fluoroscope



Corkscrew fiducials in monoplane fluoroscope



Joystick Controlled Robot Under Fluoroscopy