Tracking

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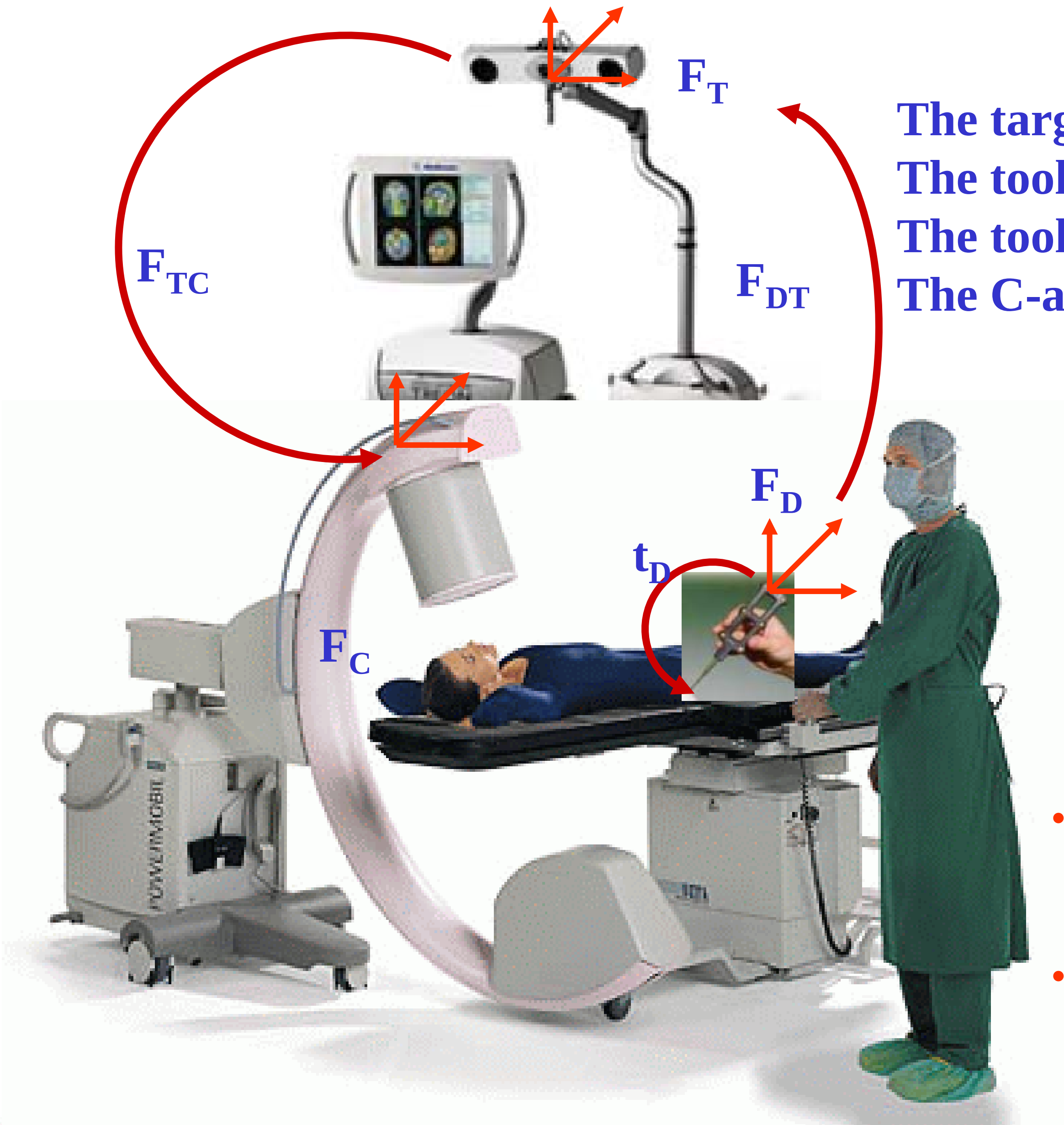
Tracking links information (imager) and action (tool)



The target anatomy is known in F_C
The tool tip is known in F_D
The tool holder is known in F_T
The C-arm is known in F_T

The tool tip t_D can be expressed in the frame of the C-arm as t_C:

$$t_{C=} (F_{TC}(F_{DT}\, t_D))$$

- How to deal with F_{TC} and F_{DT} ? – needs some maths skills that we will learn shortly…
- How to find out t_D , to start with?

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Tracking/localizer Devices

- Determine 3D positions of some markers in space relative to some base coordinate system
- Also called “3D digitizers” or “localizers”, etc.
- Many uses
- Many technologies
- Typically work like some “GPS system”
- We will review a few technologies, identify pros and cons

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Some localizer technologies

- Encoded passive manipulator
- Active manipulator
- Ultrasound
- Electromagnetic
- Optical active
- Optical passive

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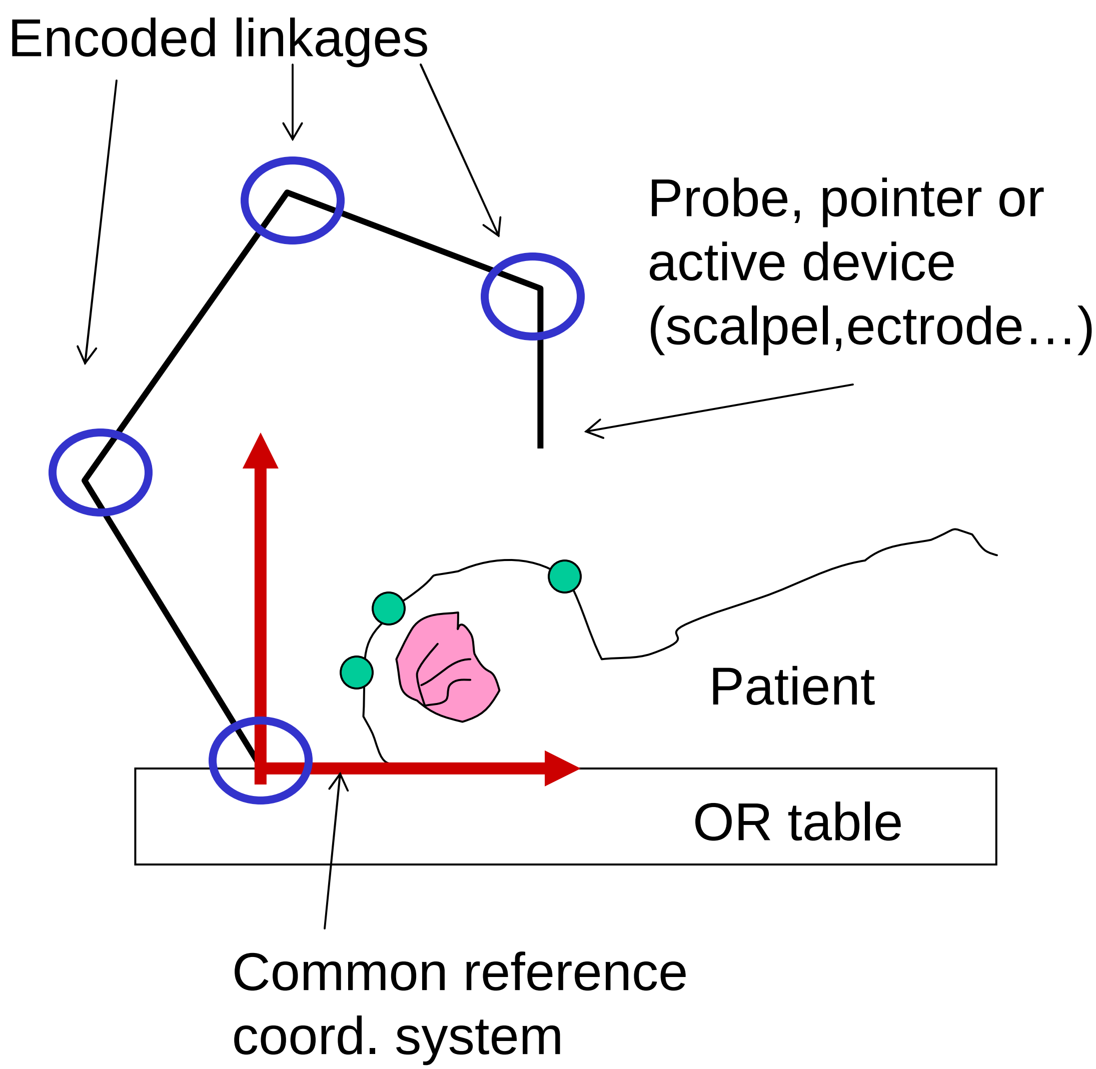
Passive mechanical linkages

- Encoders & linkage
- Advantages
  - ???
- Drawbacks
  - ???



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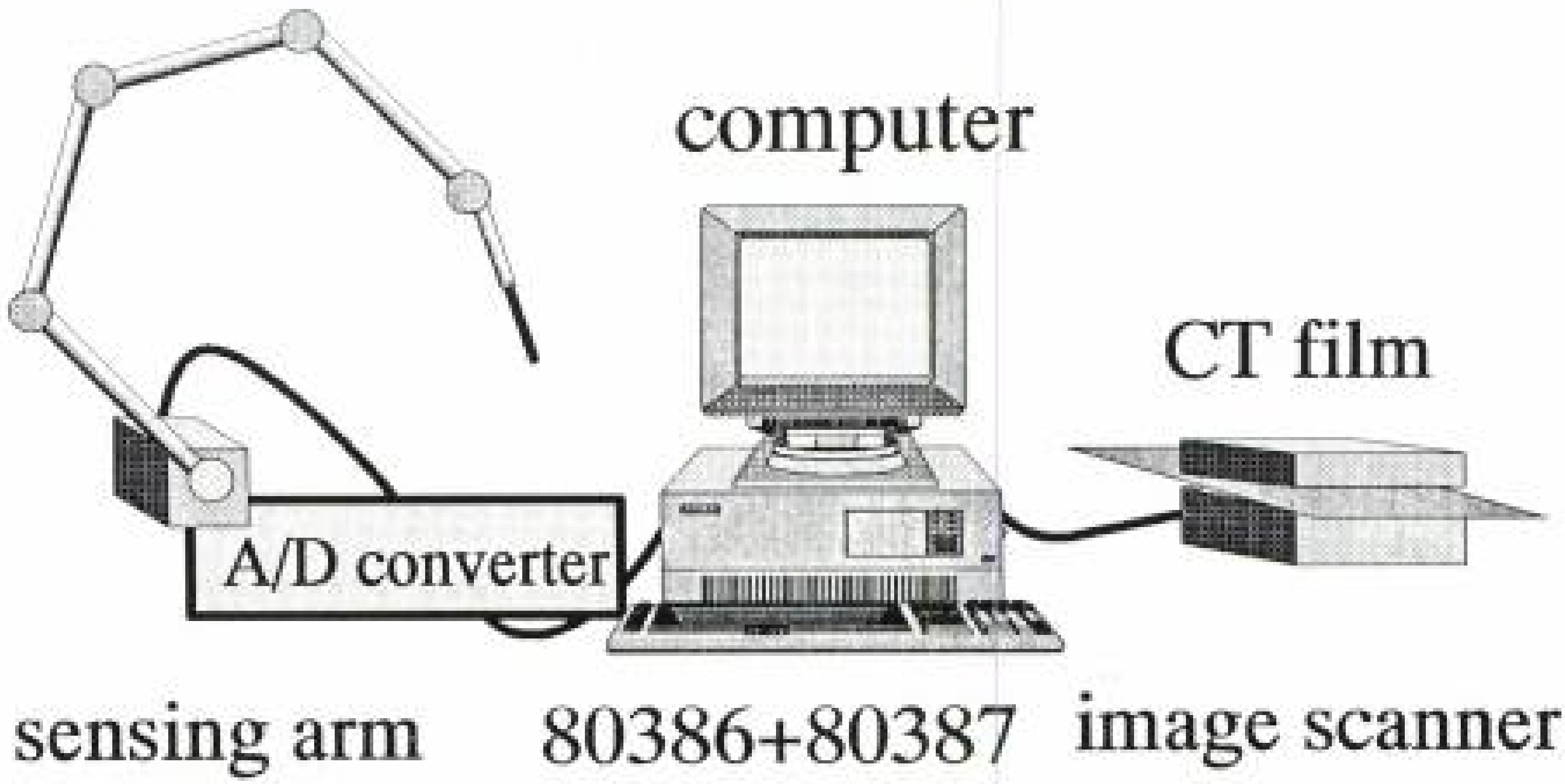

Figure 1. A schematic representation of the neuronavigator system. It consists of a microprocessor and a multi-articulated arm structure.

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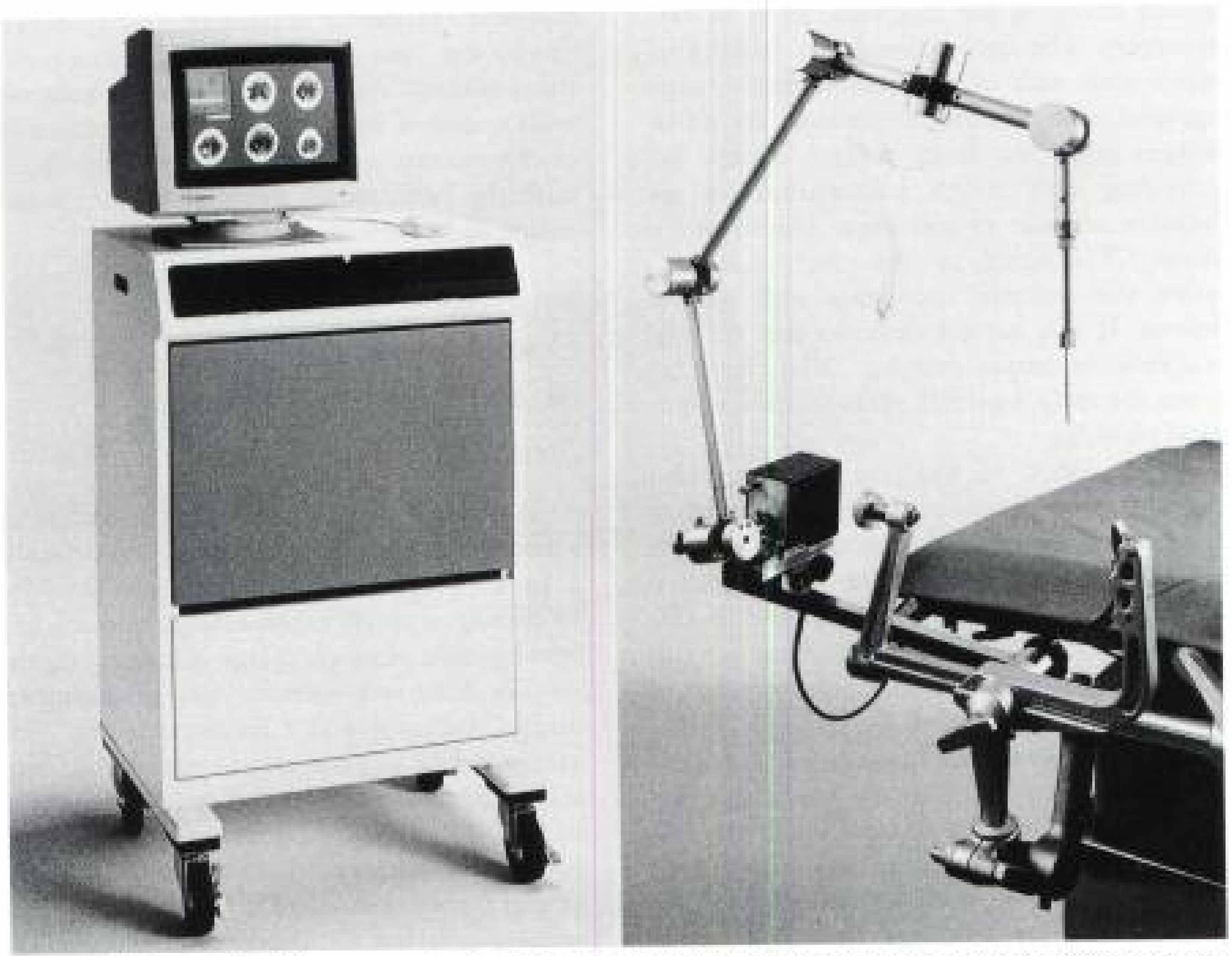

Figure 2. *Photograph of the neuronavigator. The computer system is housed in the console box on the left. The sensing arm is secured to the Mayfield skull clamp. Six CT slices are displayed on the computer screen. Two cross markers display the location of the navigator tip.*

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FIGURE 23.6 Digitizer of the second generation with ventriculoscope and docked video camera. (Center bottom) Control console.

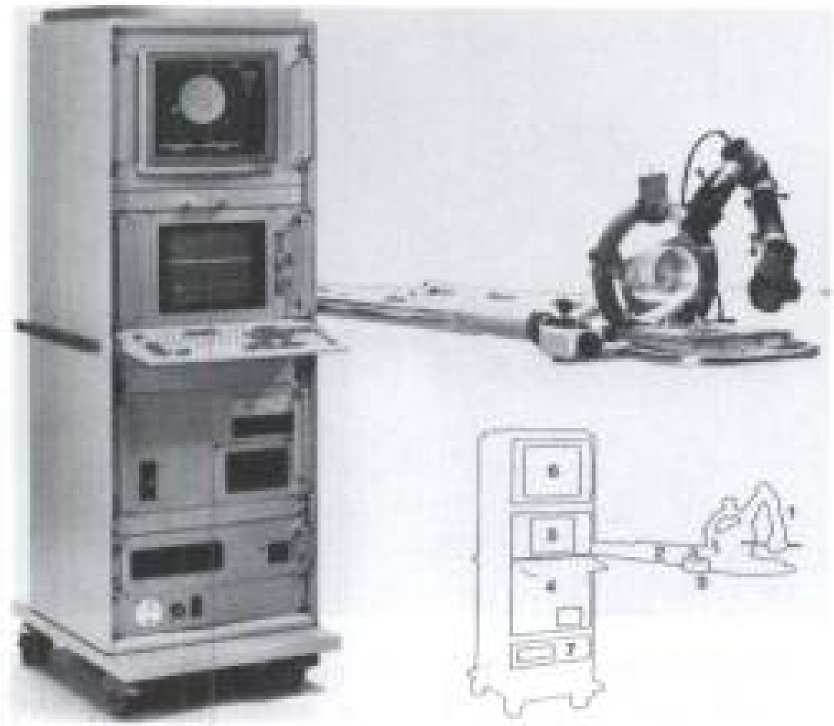

FIGURE 23.8 Overview of the ET-02 system: (1) measuring arm; (2) stretcher; (3) control console; (4) industrial computer; (5) data monitor; (6) graphics monitor; (7) 8-in. floppy drive.

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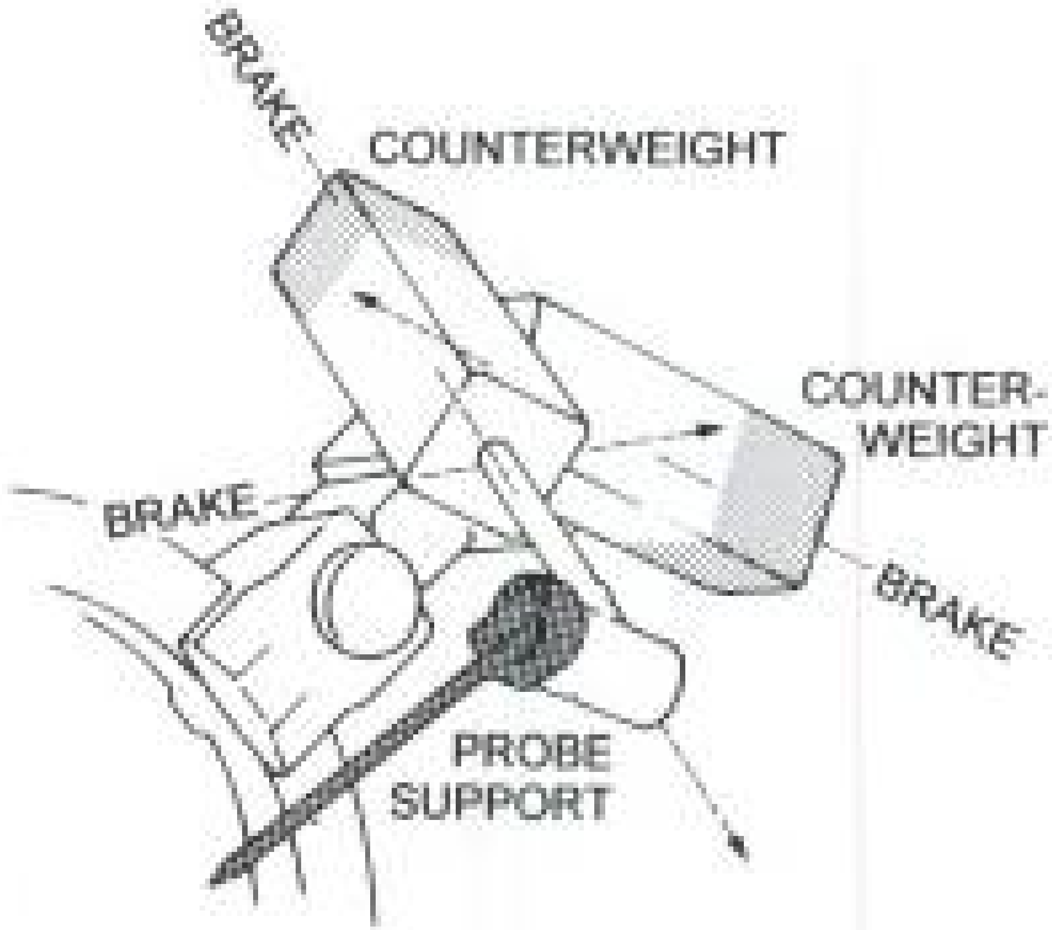

FIGURE 23.3 Mechanical principle of ET-01.

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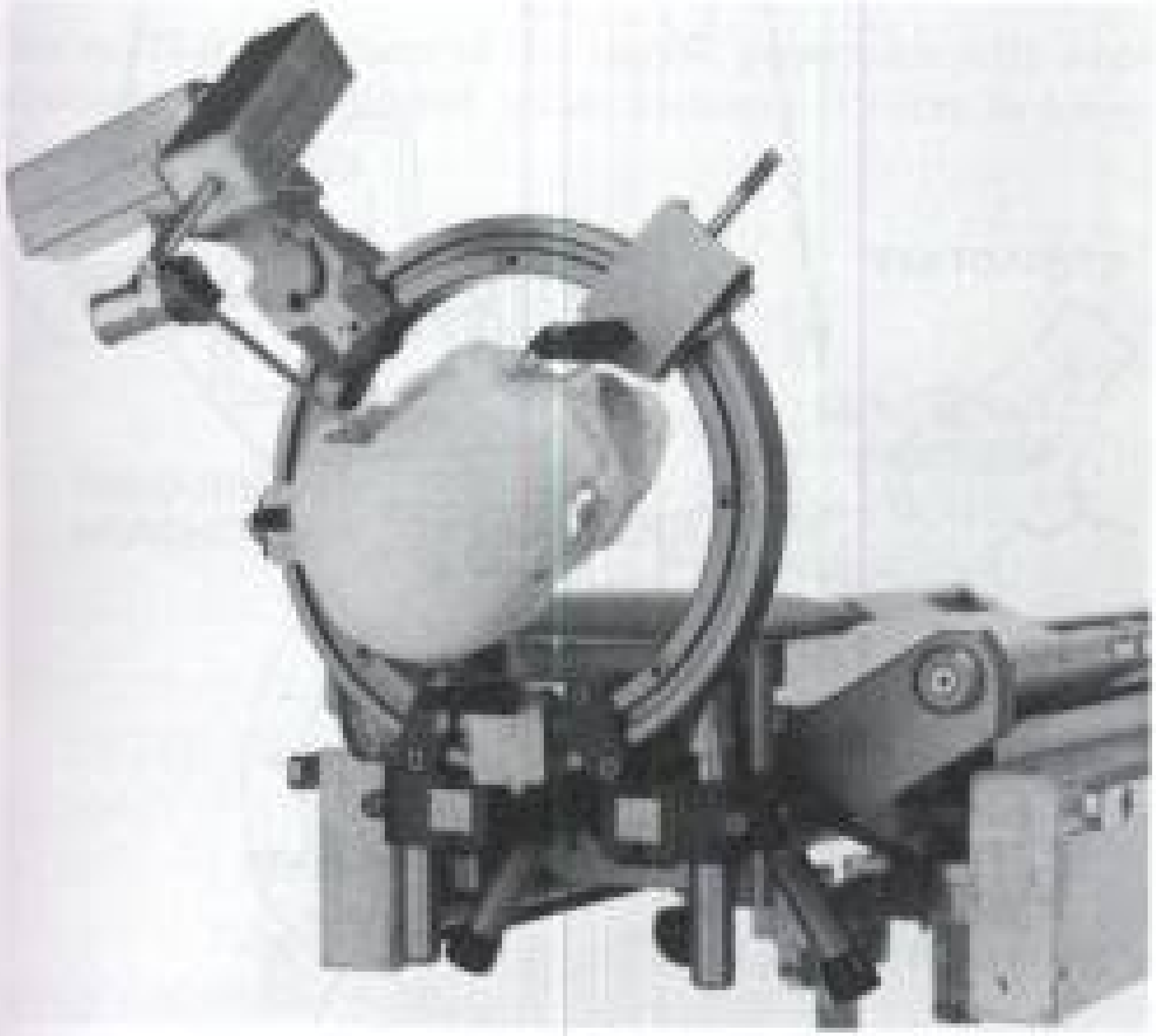

Figure 23.4 The ET-01 measuring arm with 4.5 degrees of freedom.

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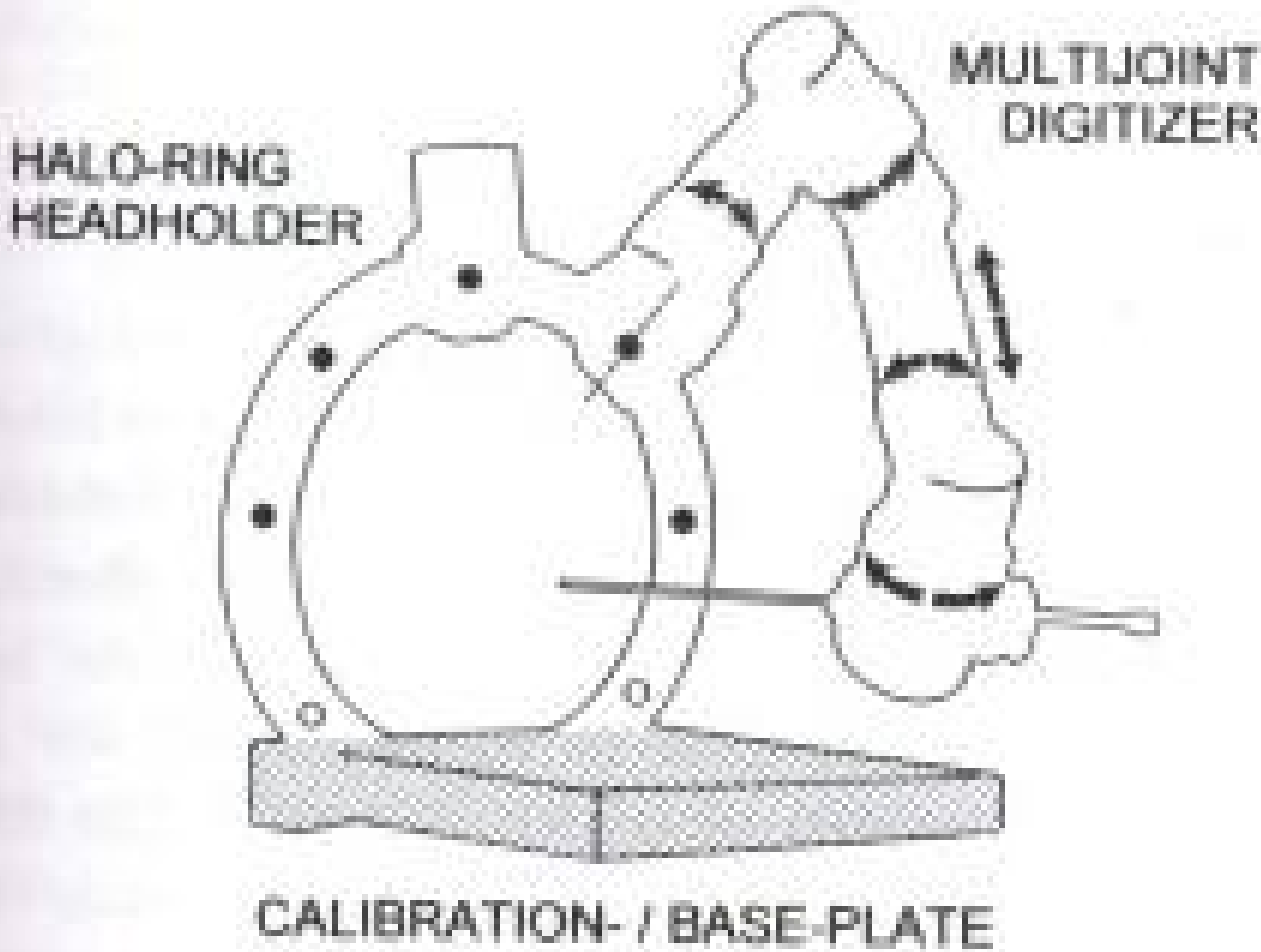

FIGURE 23.7 Four and one-half degrees of freedom in ET-02.

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FIGURE 51.2 The Aachen device for CAS with electro mechanical measuring arm (coordinate digitizer).

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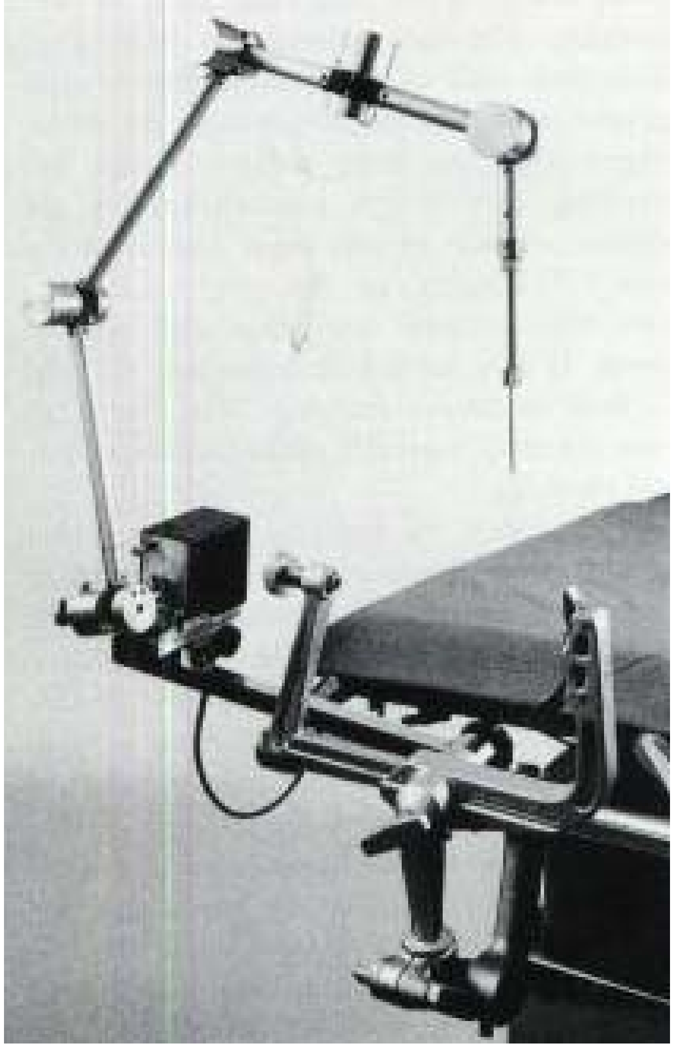
Computational Issues

1. Composition of reference frame transformations
2. Computational issues
3. Error analysis



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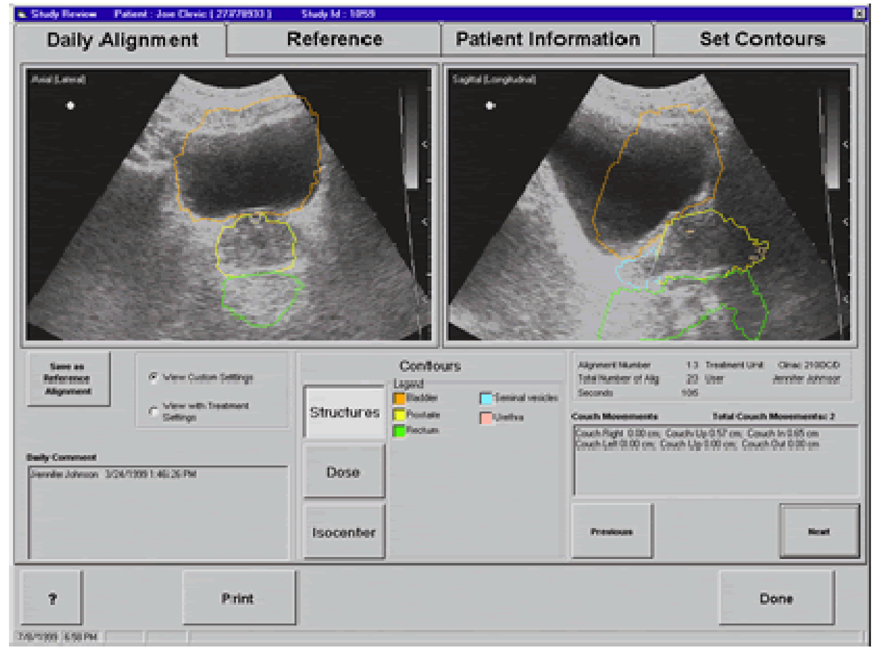
BAT for 3D tracked ultrasound



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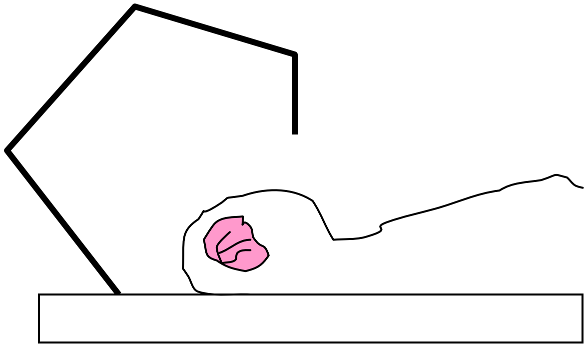
Passive mechanical linkages

- Encoders & linkage
- Advantages:
  - Simple concept
  - No line-of-sight problems
- Drawbacks
  - Clumsy
  - Confined range
  - Single reference frame
  - Error aggregation
  - Need for electronic encoder
  - Need for calibration of EACH joint
  - Reference base (head-ring) is very invasive



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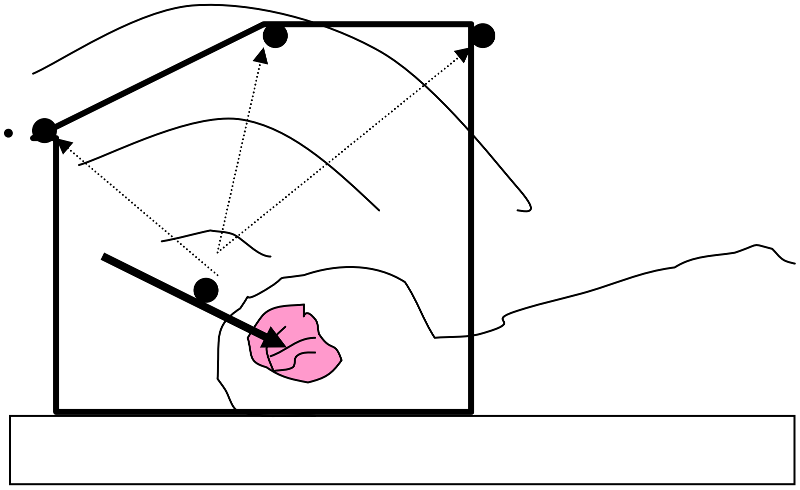
Ultrasound

- “Clickers”+microphones
- time delays give distances
- multiple distances give pos.
- Advantages
  - ???
- Drawbacks
  - ???



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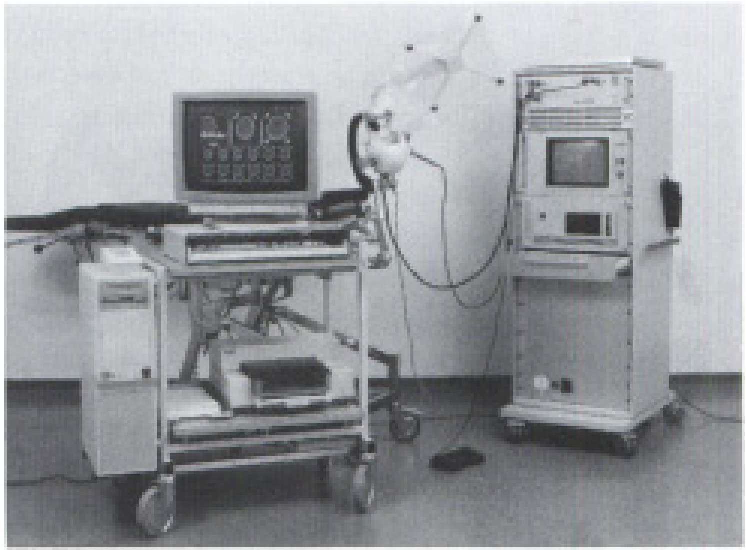

Figure 23.9 First sonic digitizer: system overview. Graphic computer (left), head-holder, sonic system (middle), SAC device, measuring computer (right).

intraoperative application. While we were evaluating the Science Accessories Corporation's (SAC) sonic system, we read about a first application of this device by Roberts [14] for the spatial, image-assisted localization of an operating microscope.

Sonic microstereometry: ET-03

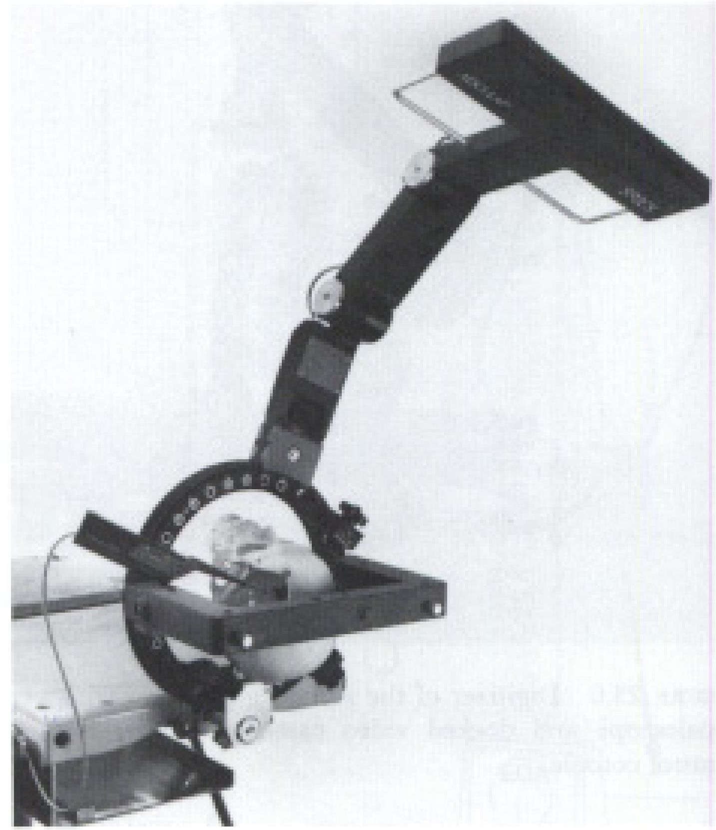

Figure 23.10 SPOCS with emitter panel (top), head-holder with detachable calibration frame, and supported targeting instrument (below left).

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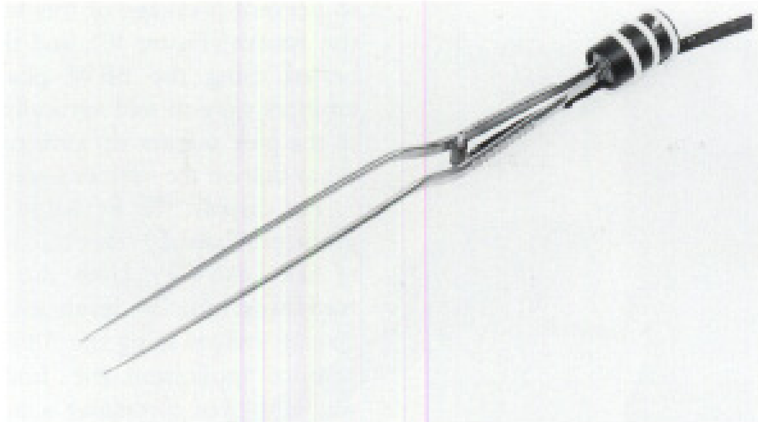

Figure 8. Sonic forceps, with wires directly attached to the emitters since the voltages involved precluded the use of a miniaturized connector.

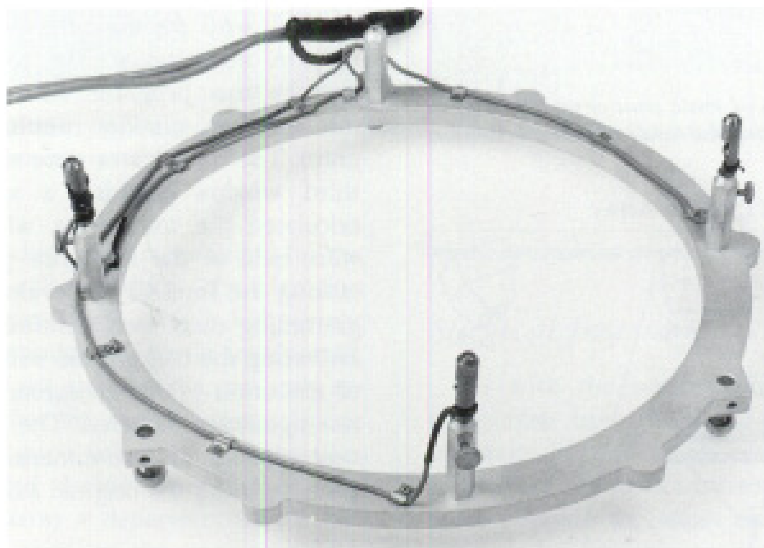

Figure 9. Sonic emitter ring, which attaches to the BRW head ring by the standard BRW ball/cam lock system; emitters can be placed at four points around the ring, allowing its use for posterior-based craniotomies.

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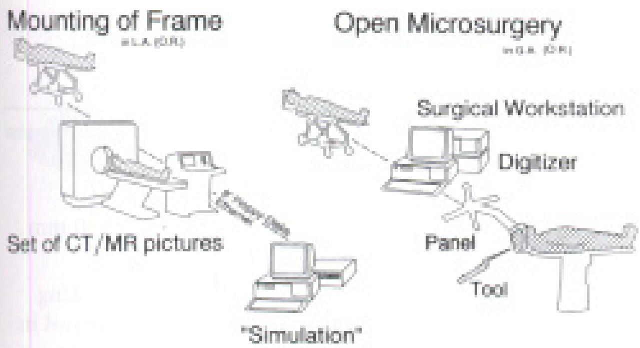

FIGURE 23.11 Sonic microstereometry. Data acquisition and operating procedure.

three microphones was docked with the ring at the same time, immediately after image data acquisition, or in a separate second procedure (see figure 23.11). The system was calibrated with a calibration panel containing three emitters, which were screwed temporarily to the ring. On the basis of the CT or MRI calibration marks, the software determines the exact position of each individual image relative to the calibration panel or base ring (first matrix operation) and then calculates the spatial relationship with the microphone panel (second matrix operation). The position of the targeting tool (one to four emitters) relative to the panel is determined finally in a third matrix operation.

The effect of interfering thermal factors could be largely eliminated by means of a measuring distance between the foot of the panel close to the head-retaining ring and the panel. Before each measuring cycle, a reference signal was emitted by the reference emitter and reached the panel microphones approximately 60 cm away in a known time of travel. Deviations (e.g., owing to temperature shifts) were taken into account auto-

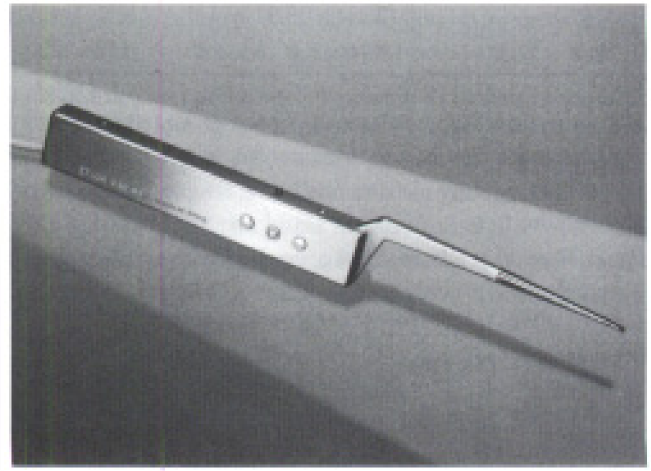

FIGURE 23.12 Bayonet-shaped standard measuring tool.

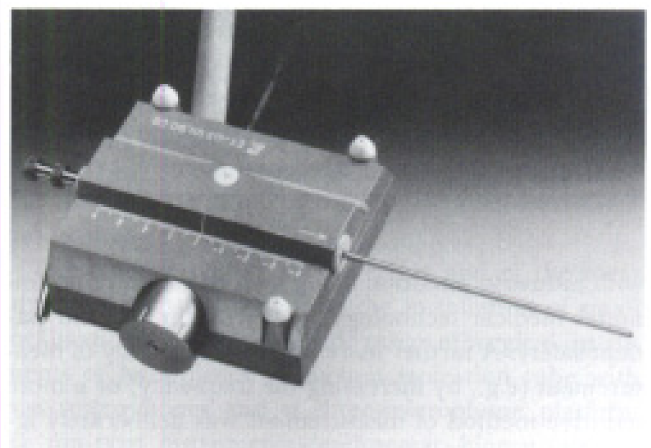

FIGURE 23.13 Measurement platform with four emitters for stereotaxy.

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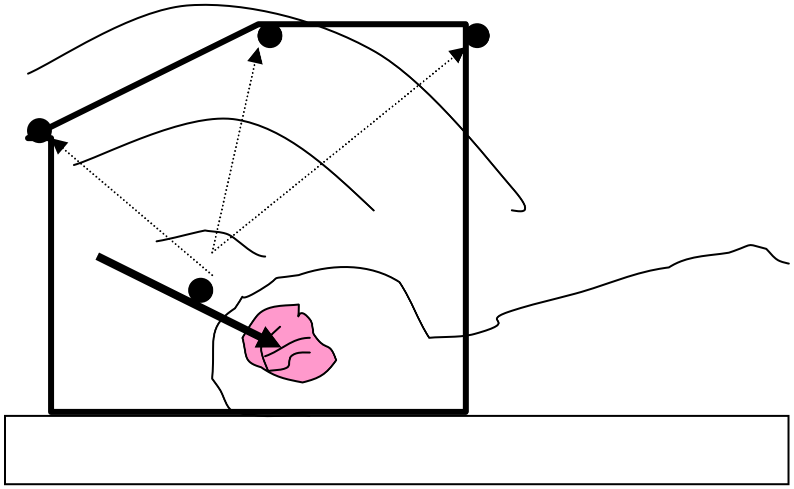
Ultrasound

- “Clickers”+microphones
- Time delays give distances
- Multiple distances give pos.
- Advantages
  - Inexpensive
  - Unobtrusive
  - Multiple rigid bodies
- Drawbacks
  - Accuracy drifts (e.g., temperature)
  - Speed of sound in diff. media
  - Lack of self-evident warning
  - Line of sight problems



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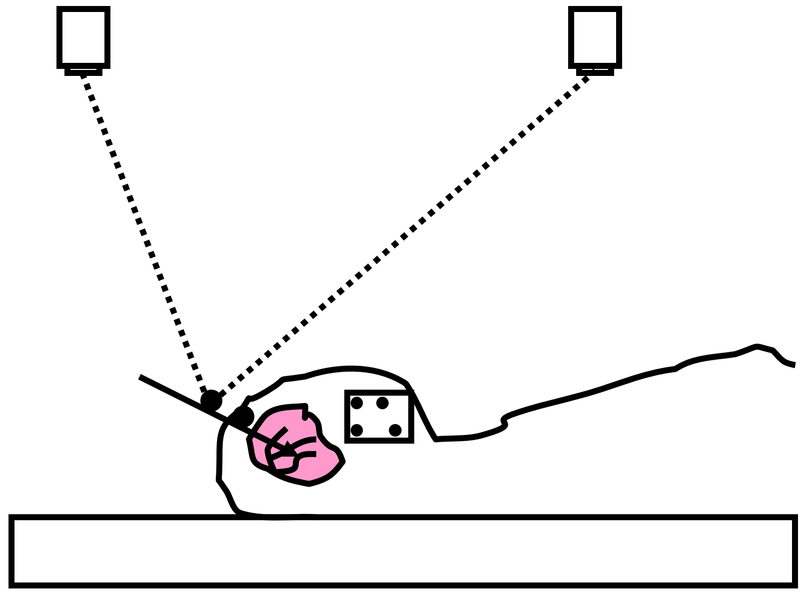
Optical passive

- Triangulate markers in standard video or infrared images
- Advantages
  - Standard components
  - Fairly fail-safe
  - Multiple devices tracked
- Drawbacks
  - Line-of-sight
  - Field of view
  - Focus/depth issues
  - Illumination-dependent
  - Camera resolution is limited
  - Differentiation between markers?



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Optical passive

- Triangulate markers in standard video or infrared images
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  - Field of view
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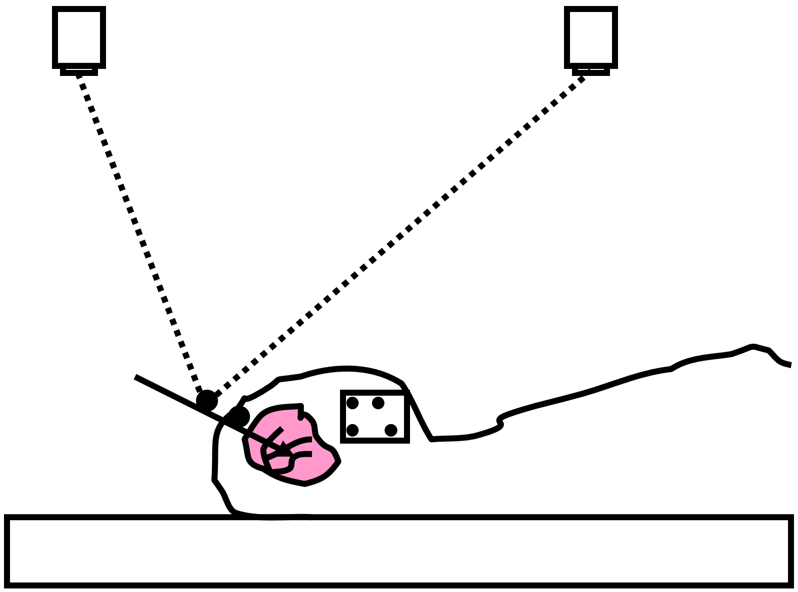
  - Illumination-dependent
  - Camera resolution is limited
  - Differentiation between markers?



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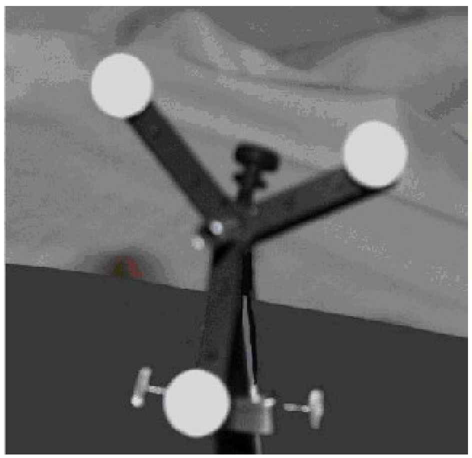
Polaris Optical Tracker



Passive Reflective Targets

Active Markers

Accuracy: 0.35 mm

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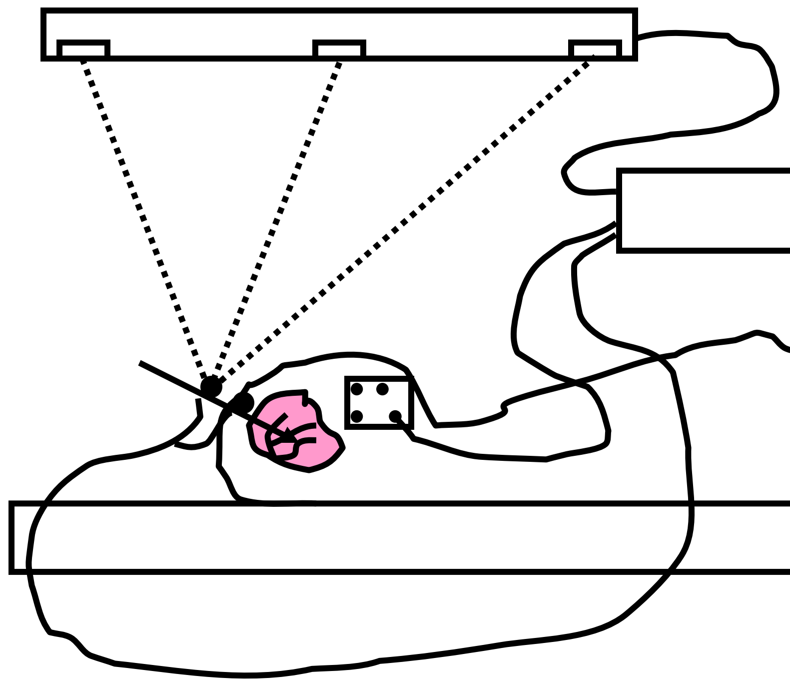
Optical active

- Track LED markers
- Triangulate to locate 3D
- E.g.: Optotrak, Pixsys
- Current "standard"
- Advantages
  - ???
- Drawbacks
  - ???



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Flashpoint Optical Tracker

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Optotrak Optical Tracker

RMS Accuracy at 2.5 m distance
0.1 mm for *x*, *y* coordinates
0.15 mm for *z* coordinate
Field of View (34x34 in)

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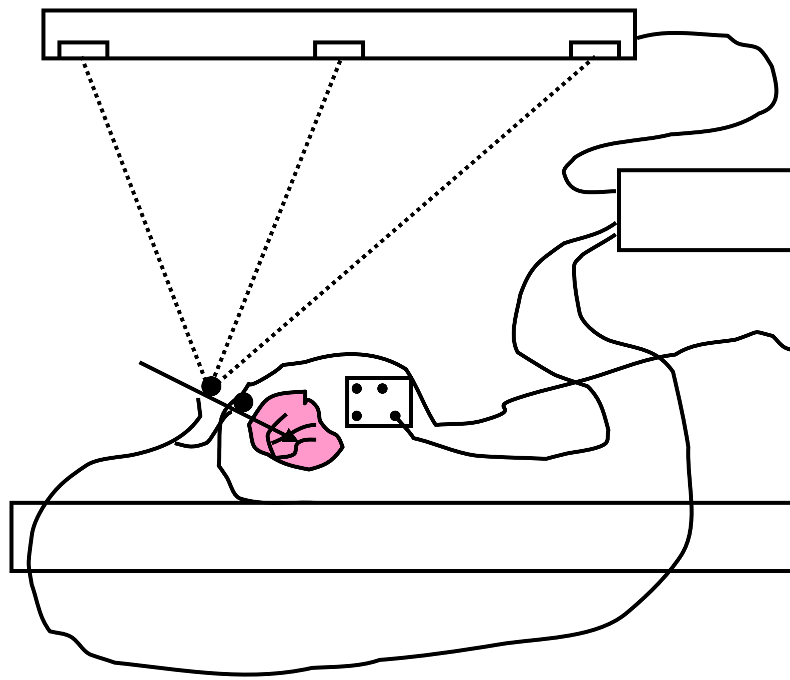
Optical active

- Track LED markers
- Triangulate to locate 3D
- E.g.: Optotrak, Pixsys
- Current "standard"
- Advantages
  - very accurate
  - multiple rigid bodies
  - versatile
  - reasonably fail-safe
  - Often obtrusive
- Drawbacks
  - line-of-sight restrictions
  - Large
  - Expensive



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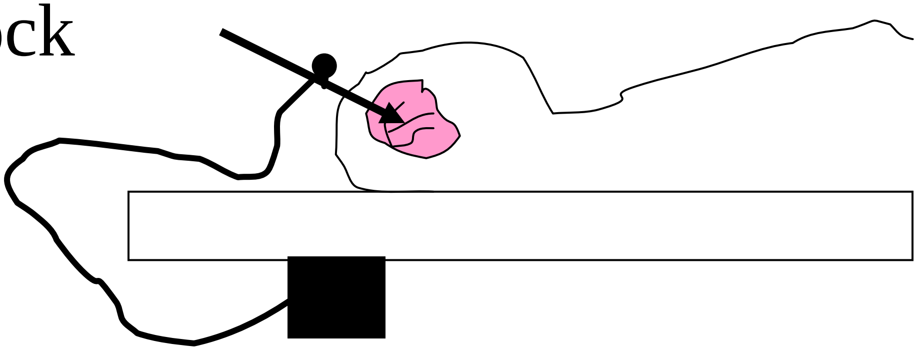
Electromagnetic

- Originally developed for fighter pilot head tracking
- Reasonably accurate 6 dof
- E.g., Polhemus, Ascension, Aurora, Flock of Birds
- Advantages
  - ???
- Drawbacks
  - ???



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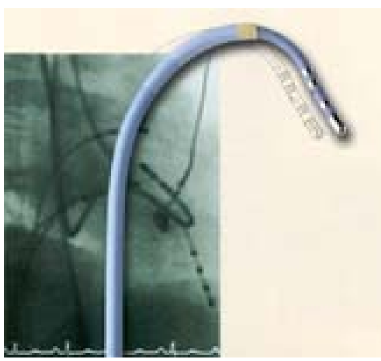
Electromagnetic Trackers

Ascension Flock of Birds

Polhemus Fastrak



J&J Biosense Webster

Northern Digital Aurora™

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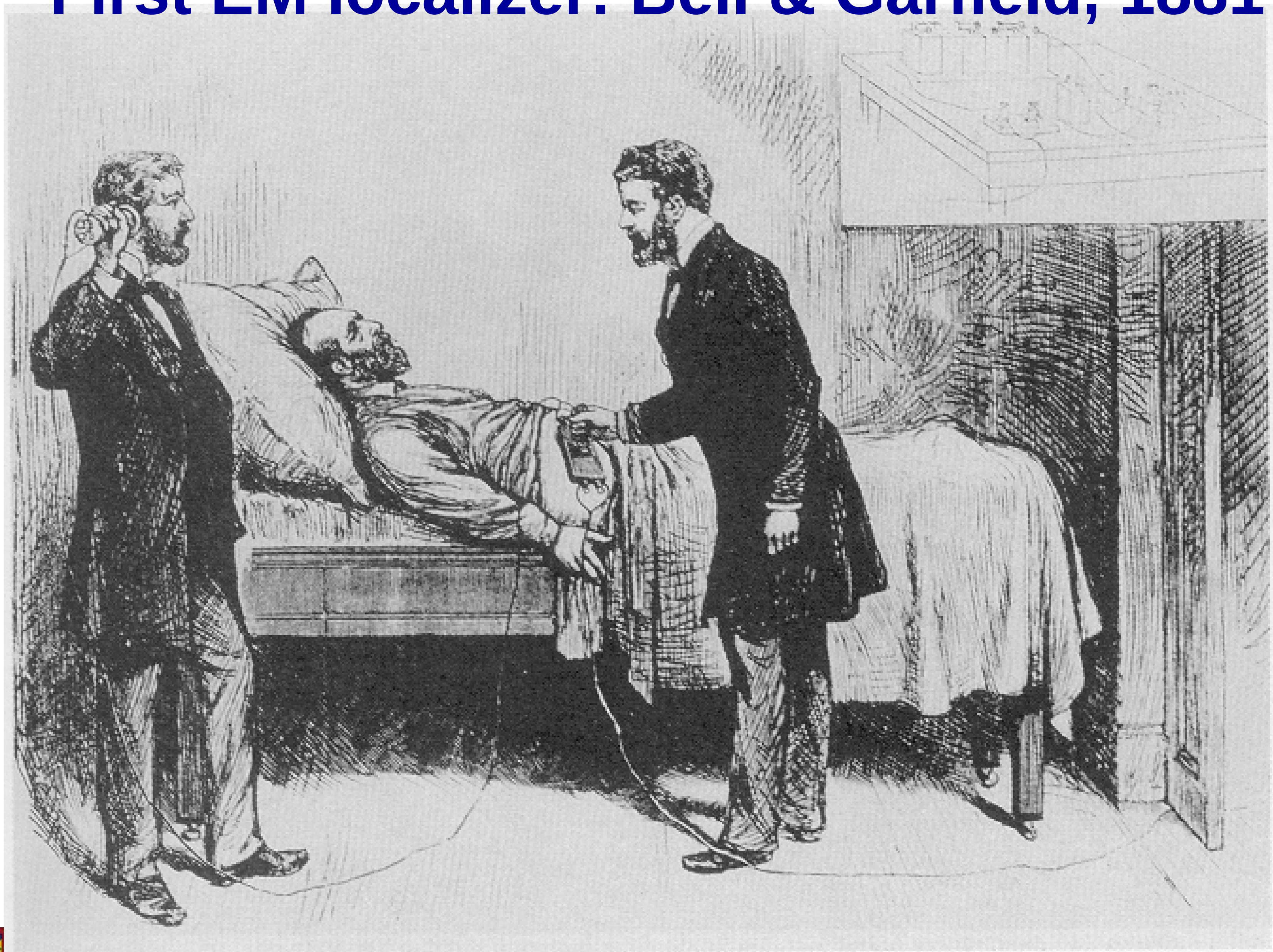
First EM localizer: Bell & Garfield, 1881



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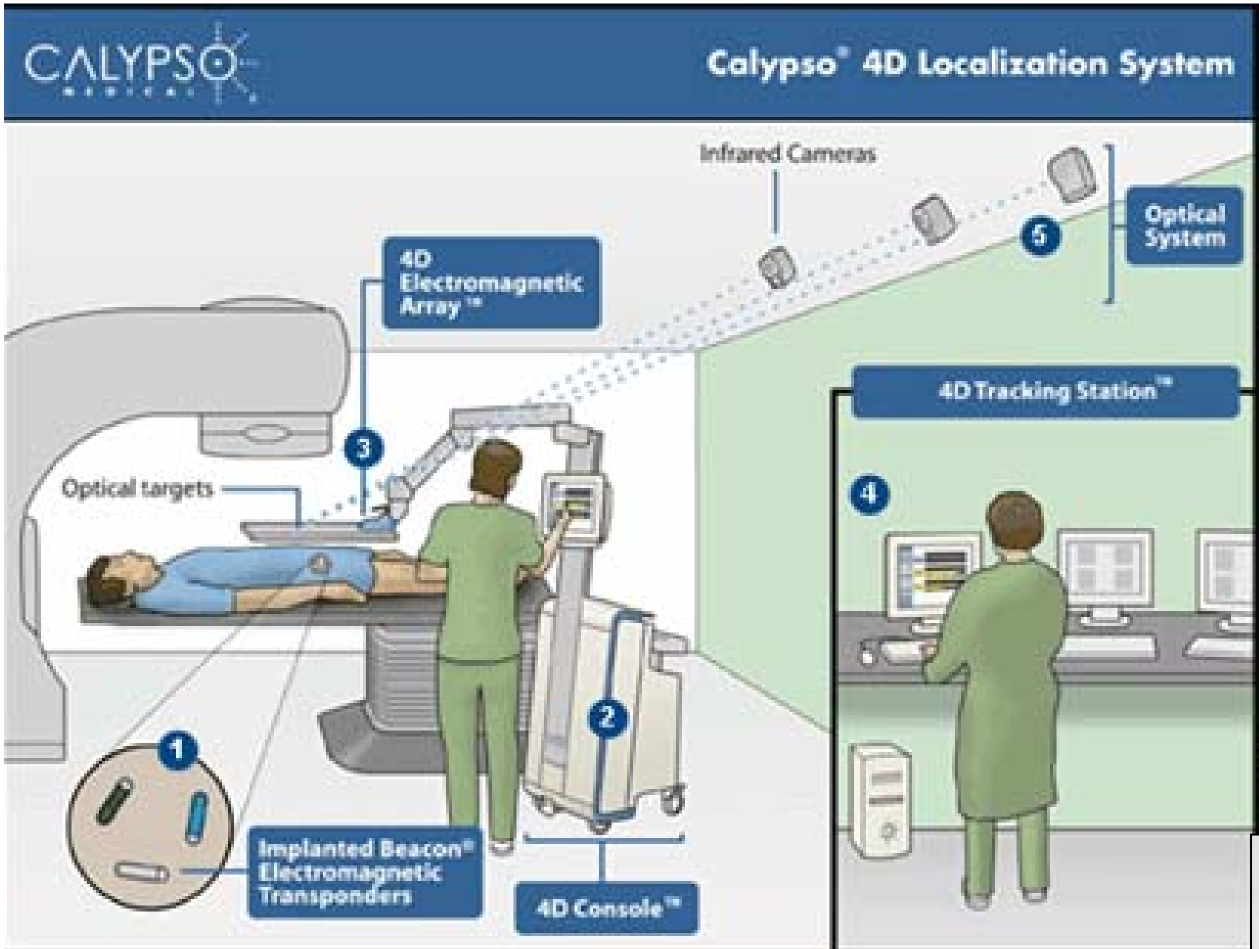
Newest EM localizer: Implanted wireless beacon



Calypso®

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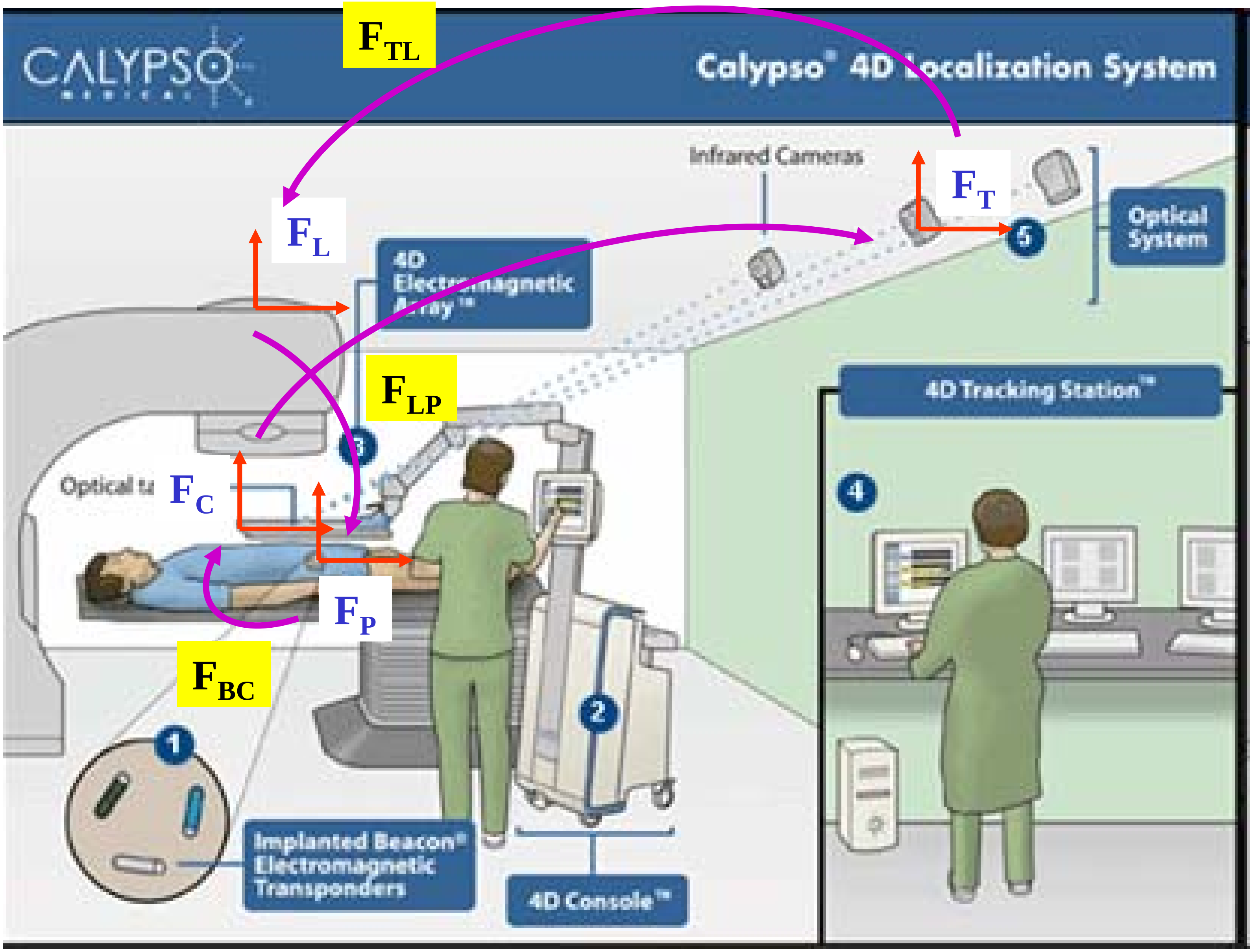
Calypso® frames and frame transformations



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