

Tracking Systems

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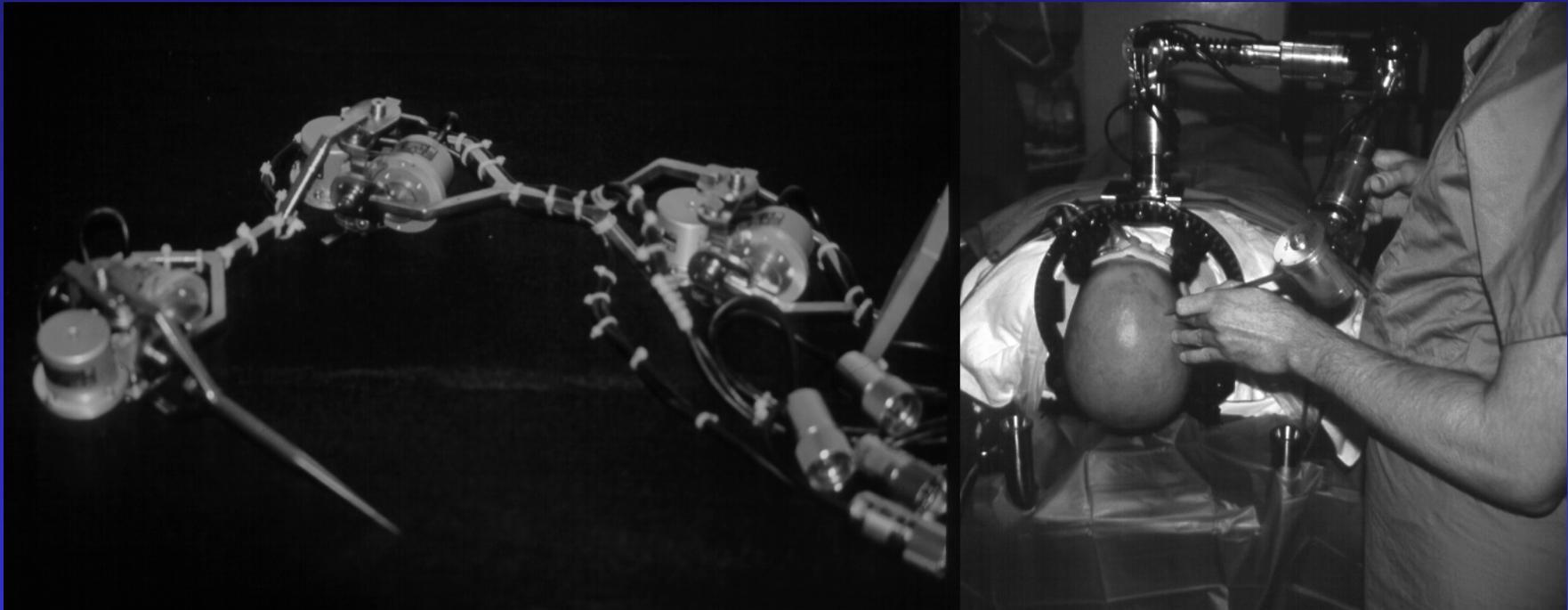
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Tracking Systems

- Track (locate) objects in space
 - 3 degrees of freedom for position
 - 3 degrees of freedom for orientation
 - 6 degrees of freedom for a rigid body
 - Most can track multiple objects
- Tracker types
 - Mechanical (early systems)
 - Optical (standard of care)
 - Electromagnetic (hot topic)

Early Mechanical Localizers: Mark I and Mark II Articulated Arms

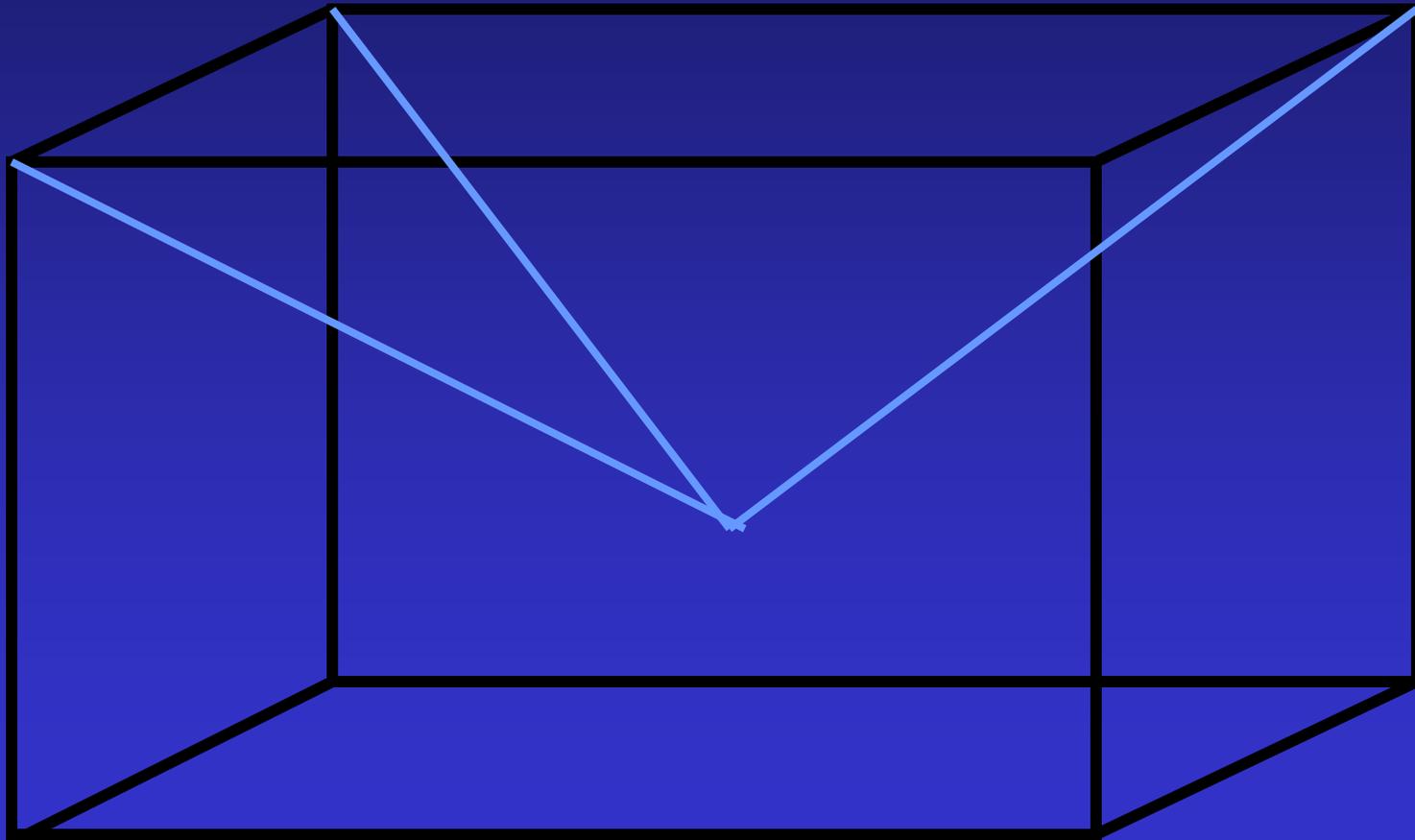


Localizer Slides Courtesy of Robert Galloway, PhD, Vanderbilt University,
Technology Guided Therapy Program

Pros and Cons of Articulated Arms

- Pros
 - Highly reliable
 - Highly accurate
 - Highly stable
- Cons
 - Cumbersome to use
 - Can easily interfere with surgical field
 - Cannot track multiple devices

Optical Localizers: Principle of Triangulation



Optical Localizer Classification

- Infrared-based (IR) tracking systems
 - Active optical systems
 - Optotrak Certus (Northern Digital Inc.)
 - Passive / active optical systems
 - Polaris Spectra and Vicra (Northern Digital Inc.)
- Videometric tracking systems
 - Micron Tracker (Claron Technology)
- Laser tracking systems
 - laserBird2 (Ascension Technology)

Infrared-based: Optotrak Certus

- Three-camera system
- Accuracy: very high
 - 0.15 mm maximum
- Field of view: large
 - Greater than 1 cubic meter
- Physical size: large
 - 1126 mm x 200 mm x 161 mm
- Tool tracking: active sensors

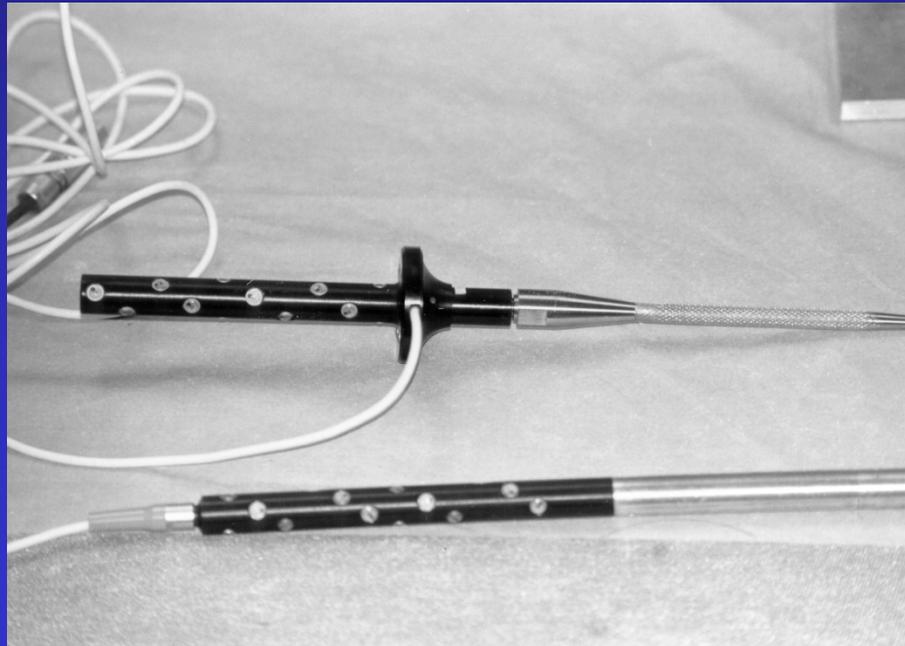


Figure courtesy of Northern Digital Inc.

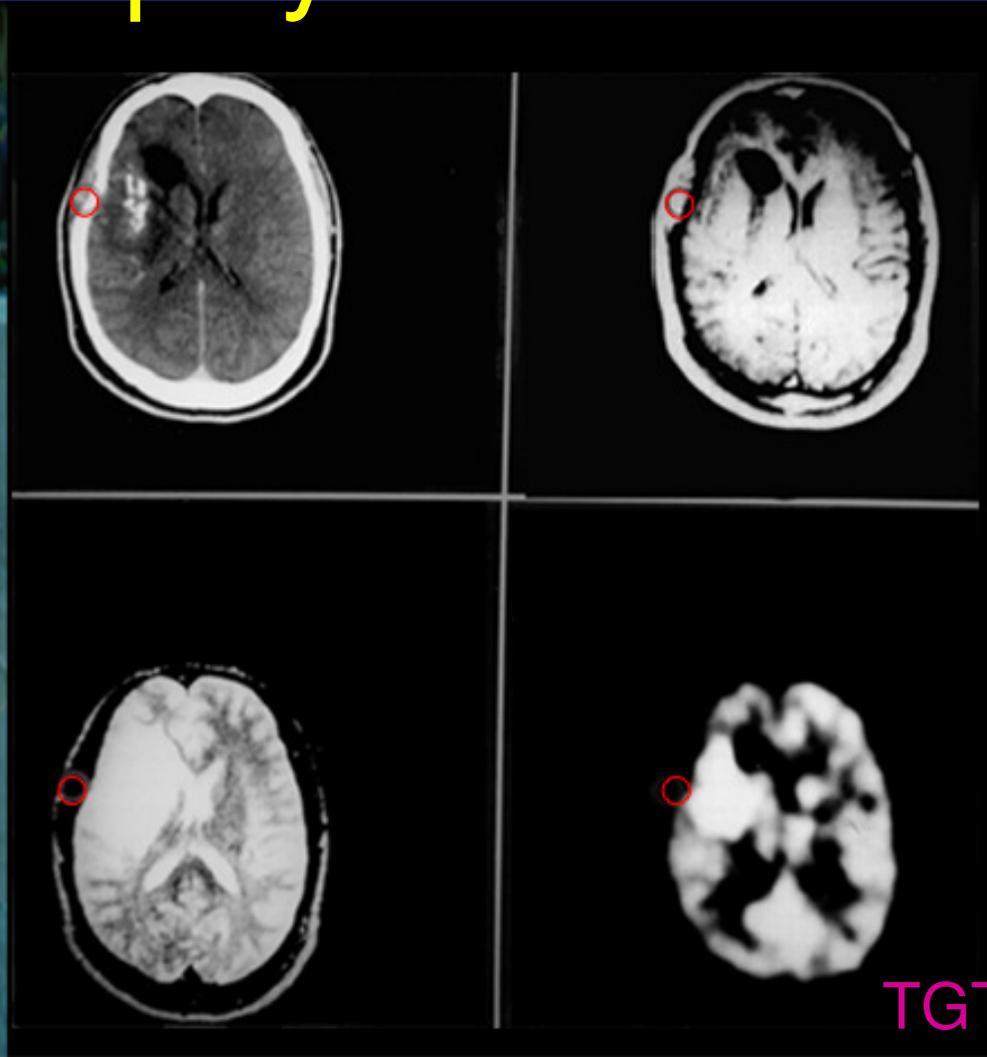
Specifications from: <http://www.ndigital.com/research/certus.php>

Multiface Tool

- > 60 degree visibility
- Requires high speed location of sources.



Optical Tracking System and Display



TGT

Polaris Optical Localizer Northern Digital Inc.

- Two 2-D sensors
- Operate with active or passive tools
- 60 Hz max
- USB interface

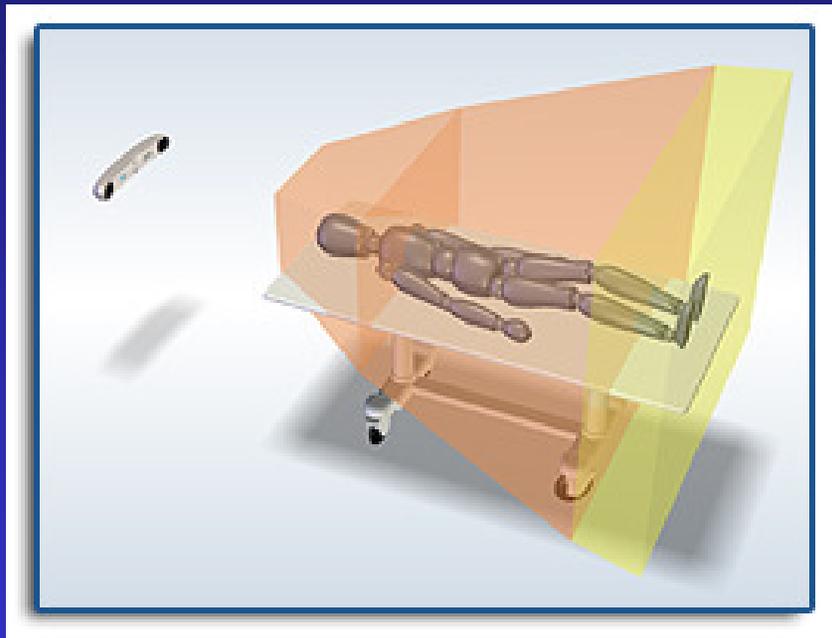


Figure courtesy of Northern Digital Inc.

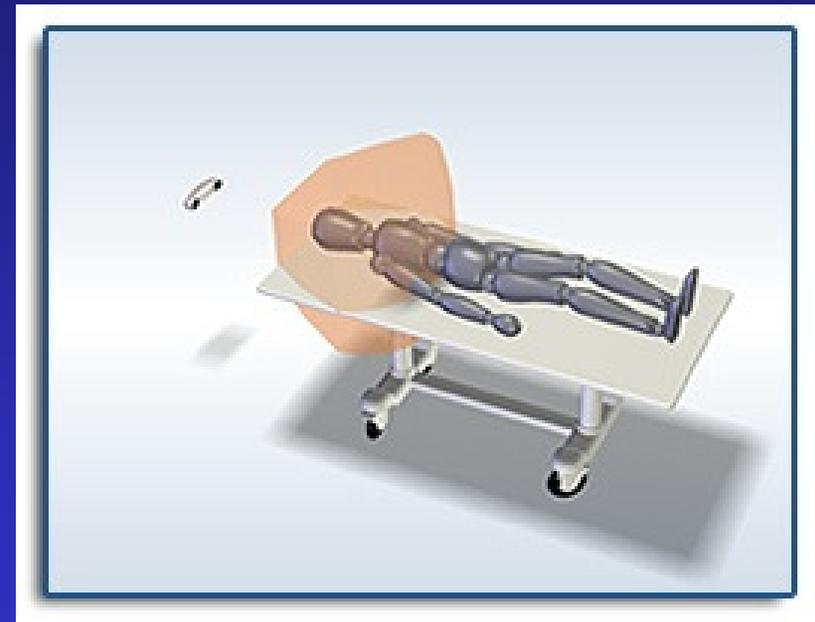
Video: <http://www.ndigital.com/medical/technology-optical.php> (active vs. passive)

Working Volume (Field of View)

Polaris Spectra



Polaris Vicra



Figures courtesy of Northern Digital Inc.

Active Tools

- Infrared-emitting markers that are activated by an electrical current
- Tool geometries can be small since the same geometry can be used multiple times
- Markers can be cleaned easily
- Tool description file can be programmed into tool

Description from Northern Digital Inc.

Passive Tools

- Spherical, retro-reflective markers that reflect infrared light emitted by the illuminators on the position sensor
- Wireless
- Track numerous tools without reducing sample rate
- Need unique geometry for each tool – tools can be large



Northern Digital Inc.

Choosing an Optical Tracking System

(courtesy Northern Digital)

- Size of measurement volume needed
- Update rate required for tracking
- Number of tools to be tracked
- Space restrictions and mounting location of system
- Integration/compatibility with current Polaris system

Setting Up Your Tracker (practical advice)

- Hardware

- Need something to mount the tracker on
 - Tripod is a good solution
 - Buy a good one
- Need some way to attach the tools to the object to be tracked
 - Can bolt directly or use clamp from Northern Digital

- Software

- Trackers now come with a USB interface
- They also have an application programming interface
 - More on this later

Another Optical System

Claron MicronTracker

- Use real-time stereoscopic vision to detect and track the pose of specially marked objects
- Objects are marked using small checkered target regions
- Firewire interface
- Video: http://www.clarontech.com/measurement_demos.php

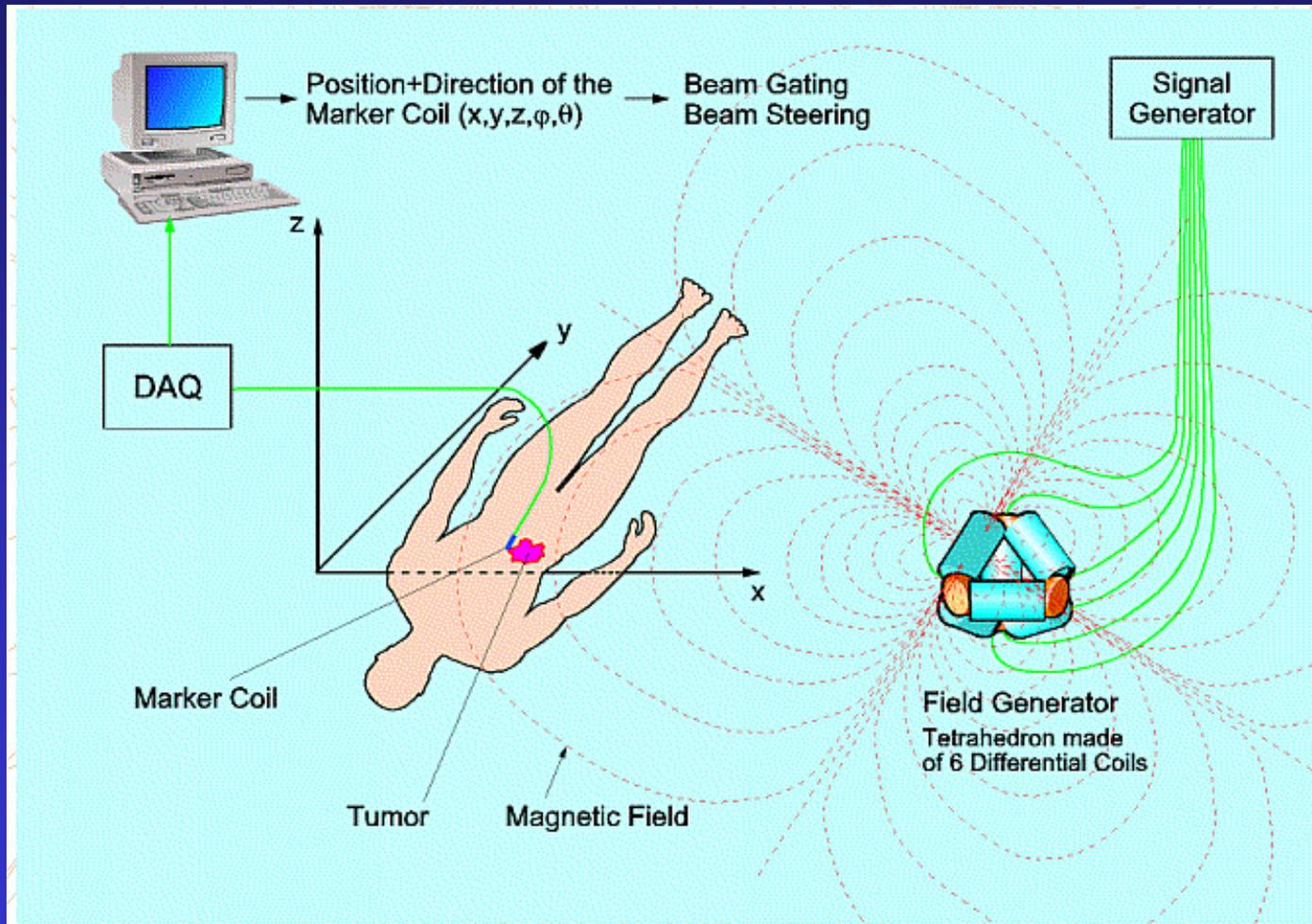


Claron Technology
Georgetown University

Electromagnetic versus Optical Tracking

- Tracking for image-guided surgery has been dominated by optical trackers
 - Advantages
 - Relatively large field of view
 - Highly accurate
 - Disadvantages
 - Require maintaining a line of sight
 - Therefore cannot track instruments inside the body
- Electromagnetic tracking
 - Does not require a line of sight
 - Therefore can track inside the body

Electromagnetic Tracking Principle of Operation



Courtesy of Northern Digital Inc.

Footnote for Panel Discussion

- The term “electromagnetic” tracking has historically been used to describe systems that are based on magnetic fields
- Some researchers may argue that these systems should be called “magnetic” spatial measurement systems since they do not depend on the electric field component of the electromagnetic wave
- However, we will use the term electromagnetic here to reflect common usage and the fact that a varying magnetic field has an associated electric component

Electromagnetic Tracker Characterization

- AC driven systems
 - FASTRAK (Polhemus Inc.)
 - Aurora (Northern Digital Inc.)
- DC driven systems
 - 3D Guidance (Ascension Technology)
- Passive or transponder systems
 - Calypso 4D system (Calypso Inc.)

Polhemus AC Driven Tracking

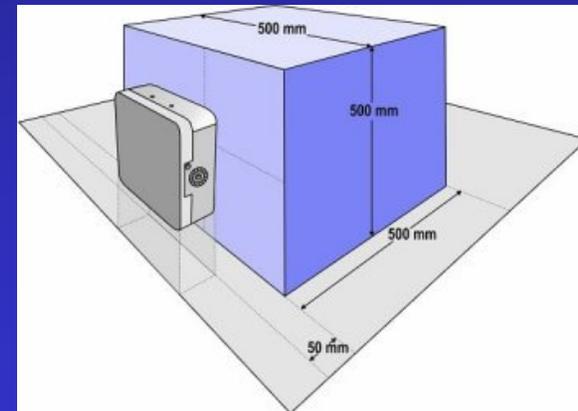
- From their website
 - Polhemus pioneered AC motion tracking
 - Unlike products based on pulsed DC technology, Polhemus trackers are not negatively affected by the earth's magnetic field, power outlets or electric motors
- Not currently used in image-guided systems though since small tools are not available



Figure courtesy of Polhemus Inc.

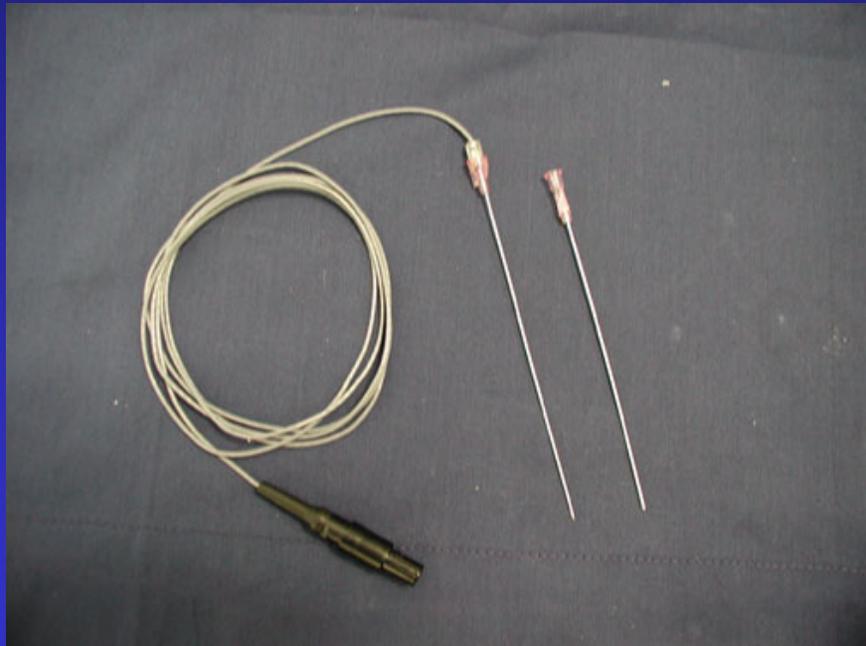
Aurora

- Enables non-line of sight tracking
- Tracks up to 8 tools using miniature sensor coils
- Maximum rate of 40 Hz
- Measurement volume
 - 500 mm cubed
 - Starting 50 mm from field generator

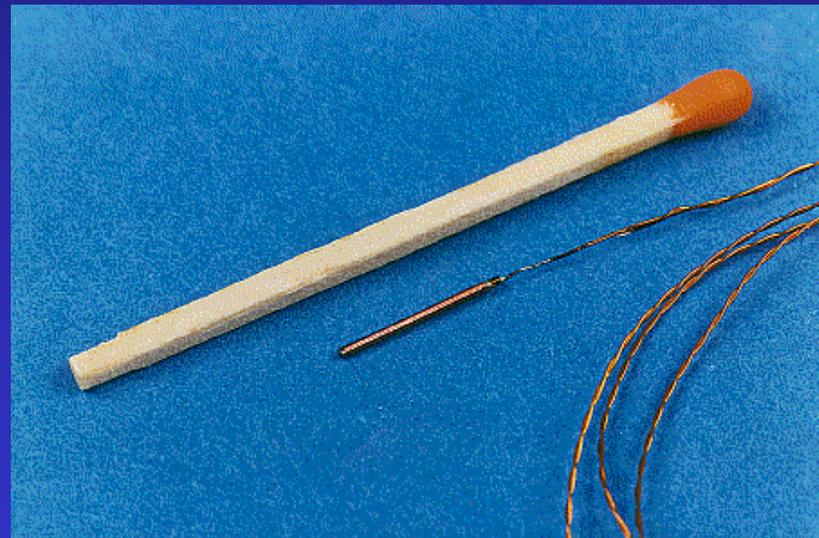


Figures courtesy of Northern Digital

Electromagnetically Tracked Biopsy Needles



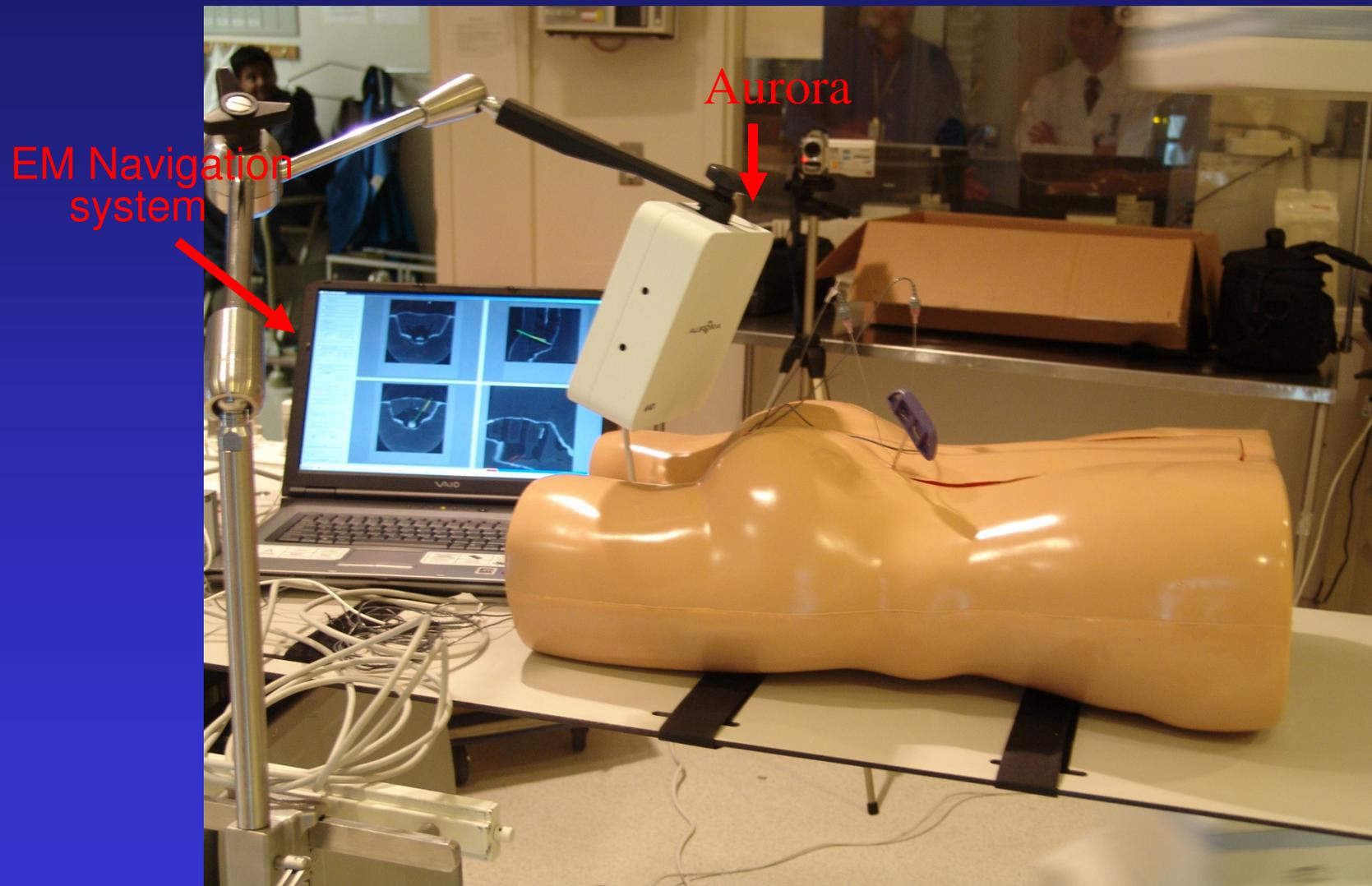
MagTrax Needle, Traxtal Inc



Courtesy of Northern Digital Inc.

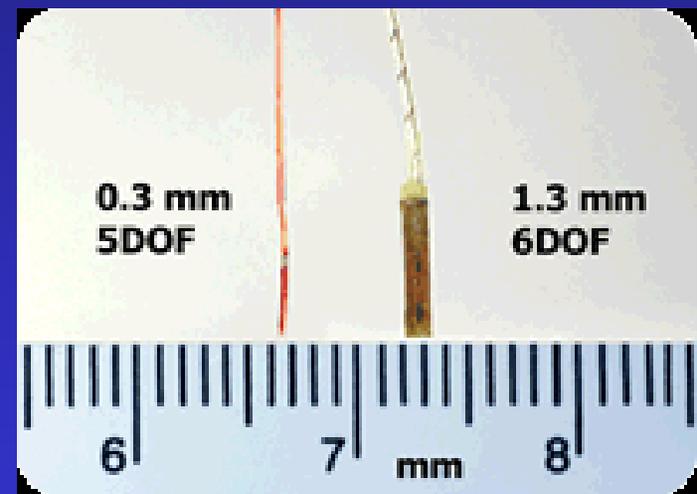


Vertebroplasty



3D Guidance (Ascension)

- Track up to eight miniaturized 6 DOF sensors or twenty-four 5 DOF sensors simultaneously
- Driven by quasistatic direct current (DC)
 - Can be more immune to eddy current distortions caused by common conductive metals, such as stainless steel (300 series), titanium, and aluminium



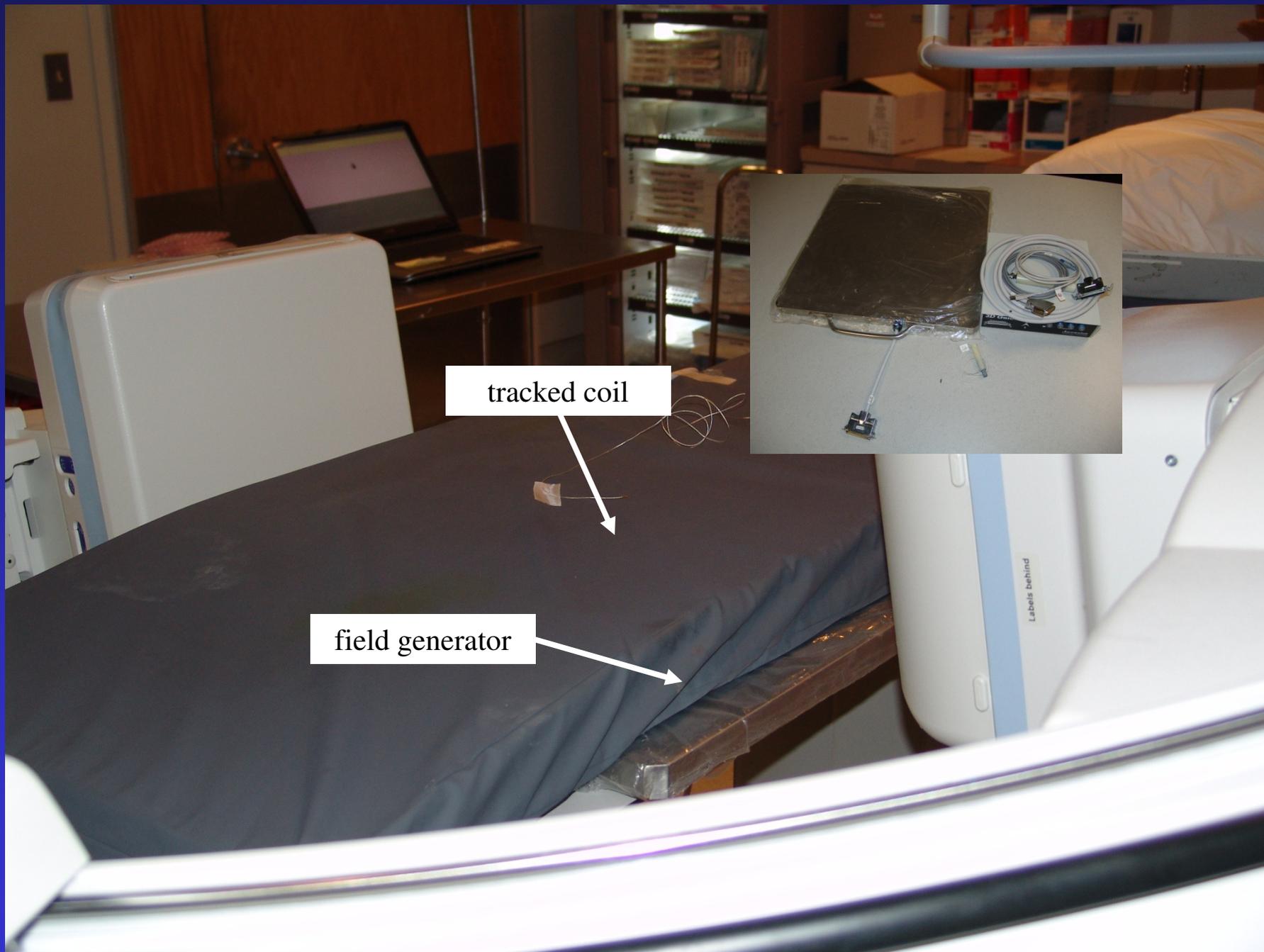
Figures courtesy of Ascension

“Metal Immune” Flat Transmitter

- Placed beneath a patient to negate any possible distortion of measurements by ferrous metal in an OR or procedural table
- ± 20 cm X, Y, 10--46 cm Z coverage
- Radio-translucent and radio-opaque models available



Figures courtesy of Ascension



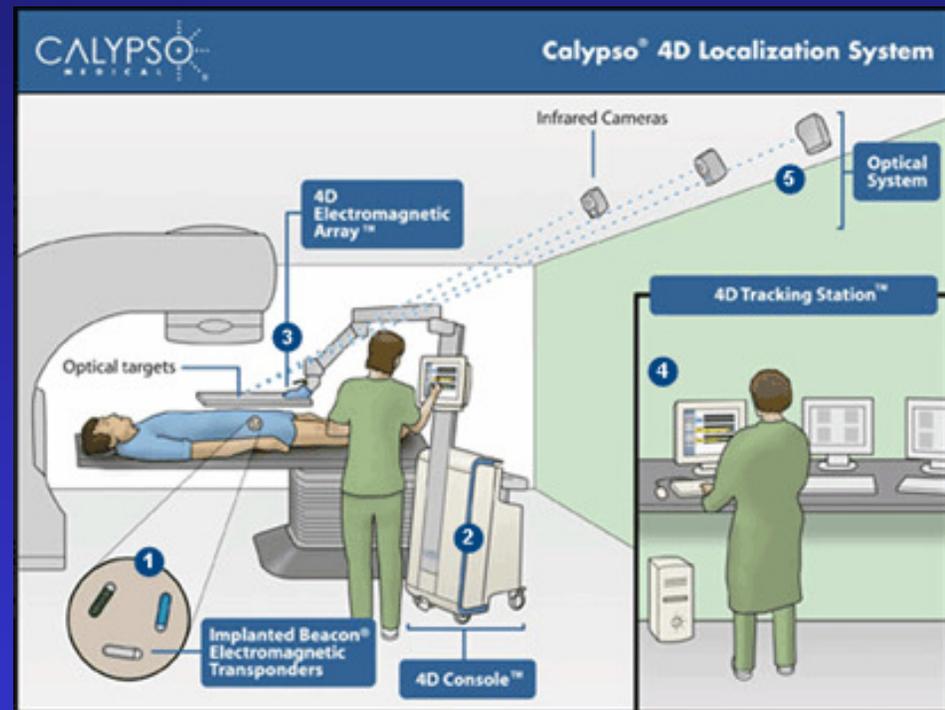
tracked coil

field generator

Calypso System for Prostate External Beam Radiation

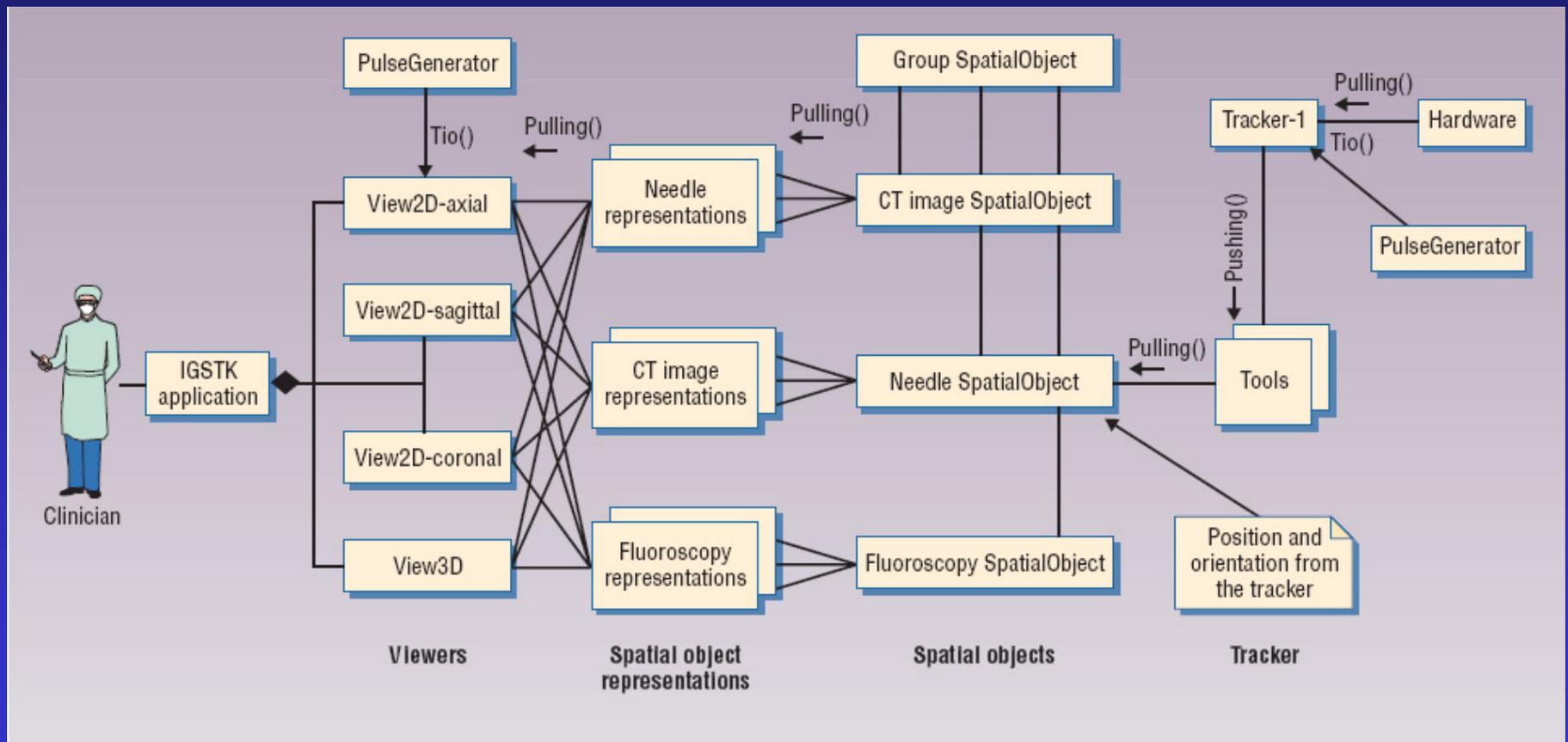


- System components
 - 1) Beacon electromagnetic transponder (implanted in patient)
 - 2) 4D console (in room monitoring for setup)
 - 3) 4D electromagnetic array
 - 4) 4D tracking system (out of room monitoring)
 - 5) Optical system (for initial positioning)



Figures courtesy of Calypso Medical

IGSTK Open Source Software (image-guided surgical toolkit: igstk.org)



How to Choose a Tracker

- Must be based on clinical application
- First, do you need to track inside the body?
 - Choice of electromagnetic versus optical
- Second, what is the tracking volume required?
- Third what are the tools required?
- Good topic for panel discussion

Acknowledgments

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