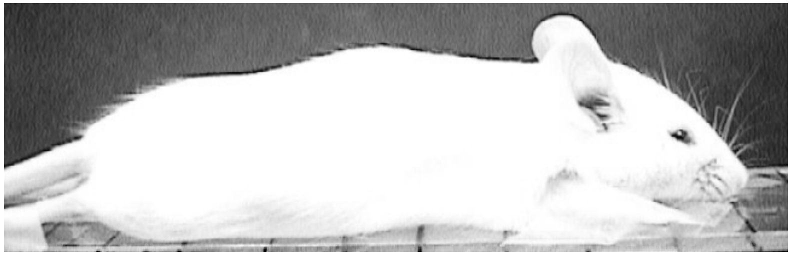

Automated Pose Determination for Unrestrained, Non-anesthetized Small Animal Micro-SPECT and Micro-CT Imaging

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Outline

- Research motivation and project overview
- Infrared reflector tracking
- Experimental setup and results
- Summary and future goals

Research motivation
X-ray micro-CT and SPECT Imaging

- **Pharmaceutical testing requires screening test subjects for drug effects**

- **Mice are invaluable tools for modeling human disease, testing new drugs**

Research motivation
X-ray micro-CT and SPECT Imaging

- New research tools are being developed at ORNL for high-resolution small animal imaging
- This technology is being transferred to industry to support small animal research

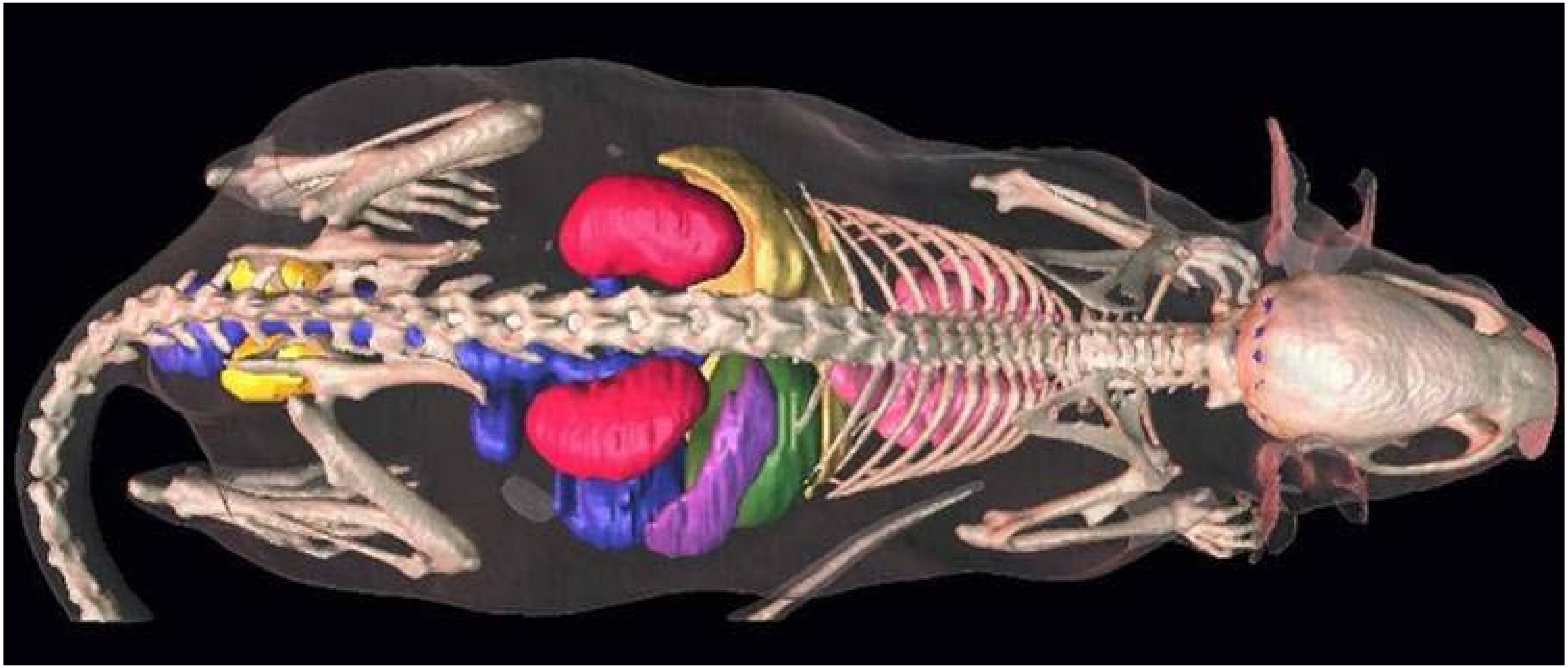
X-ray micro-CT image of 4-week old mouse

X-ray micro-CT scanner

http://www.imtekinc.com

Research motivation
X-ray micro-CT and SPECT Imaging

- ***X-ray micro-CT imaging*** provides detailed anatomical information



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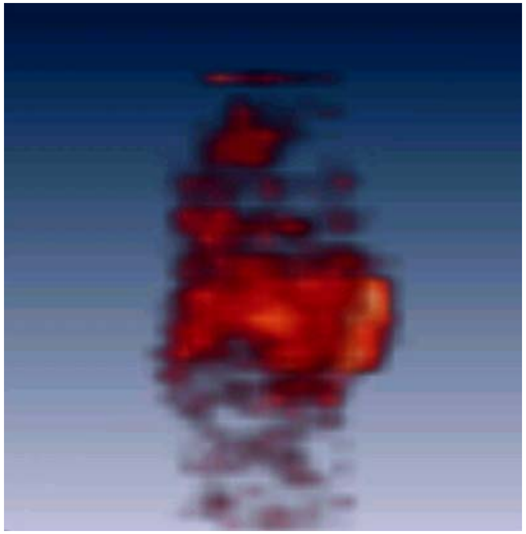
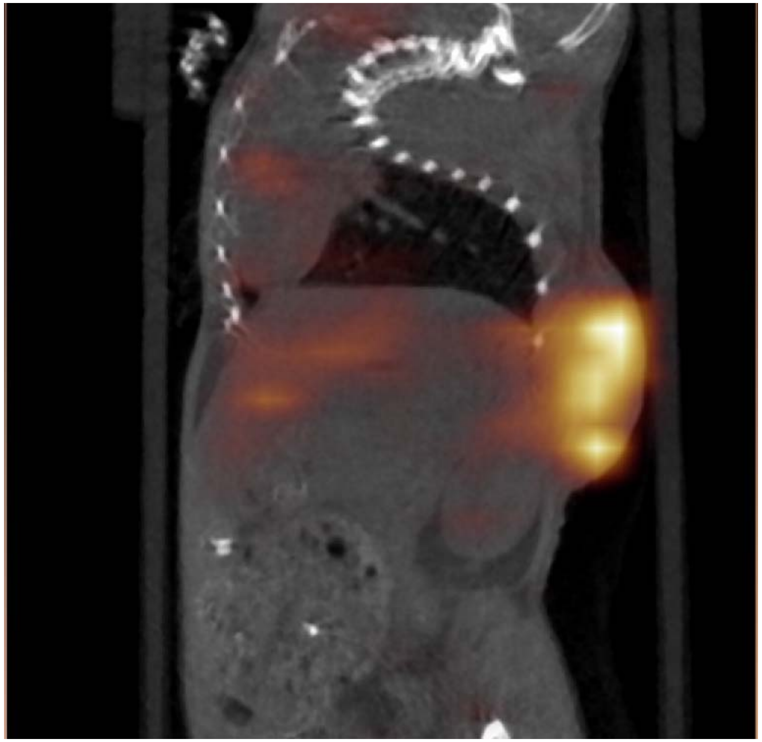
Research motivation
X-ray micro-CT and SPECT Imaging

- ***Single Photon Emission CT* (SPECT)** used for functional imaging
- Dual Modality Example – Amyloid targeted Fab labeled with I-125



micro-SPECT volume

registered micro-SPECT and micro-CT volumes



registered micro-SPECT and micro-CT slices

Research motivation

Live Animal micro-CT Imaging: Problems

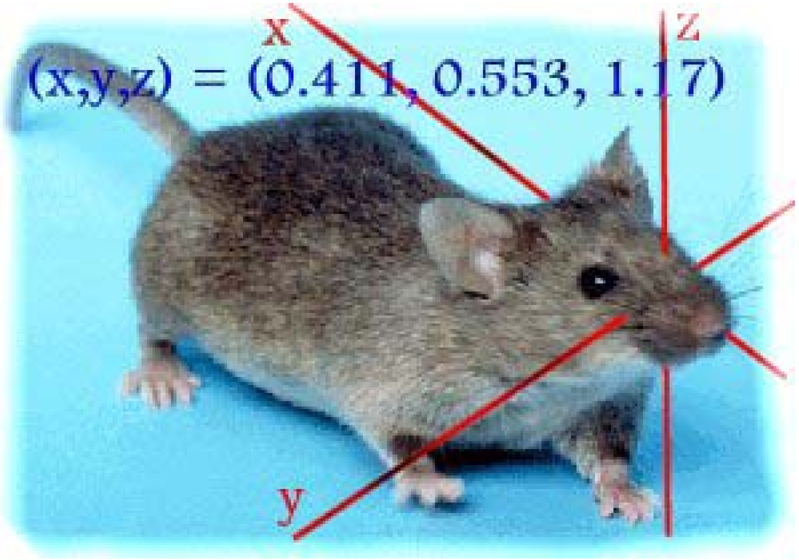
- Monitoring physiologic processes requires that the animal is alive during the scan
- Anesthesia and physical restraint can interfere with these physiologic processes
- Clinical applications include imaging of children, Parkinson's patients, and Alzheimer's patients

Project Overview

Live Animal micro-SPECT Imaging

- By tracking the position of the animal, scan data can be corrected for animal motion

- Two tracking methods under development:
  - Infrared reflector tracking (current)
  - Laser profiling (in progress)

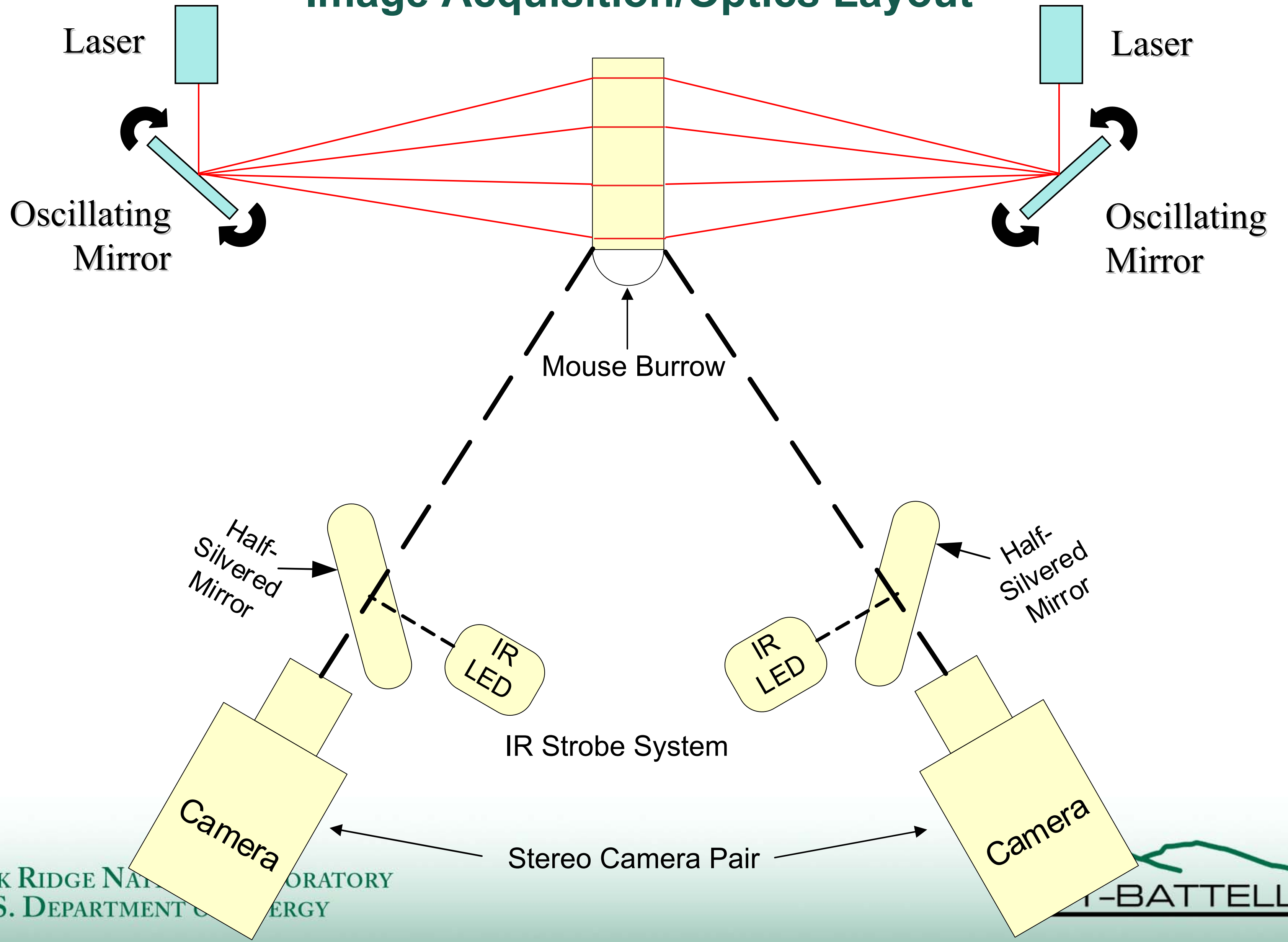


Project Goals

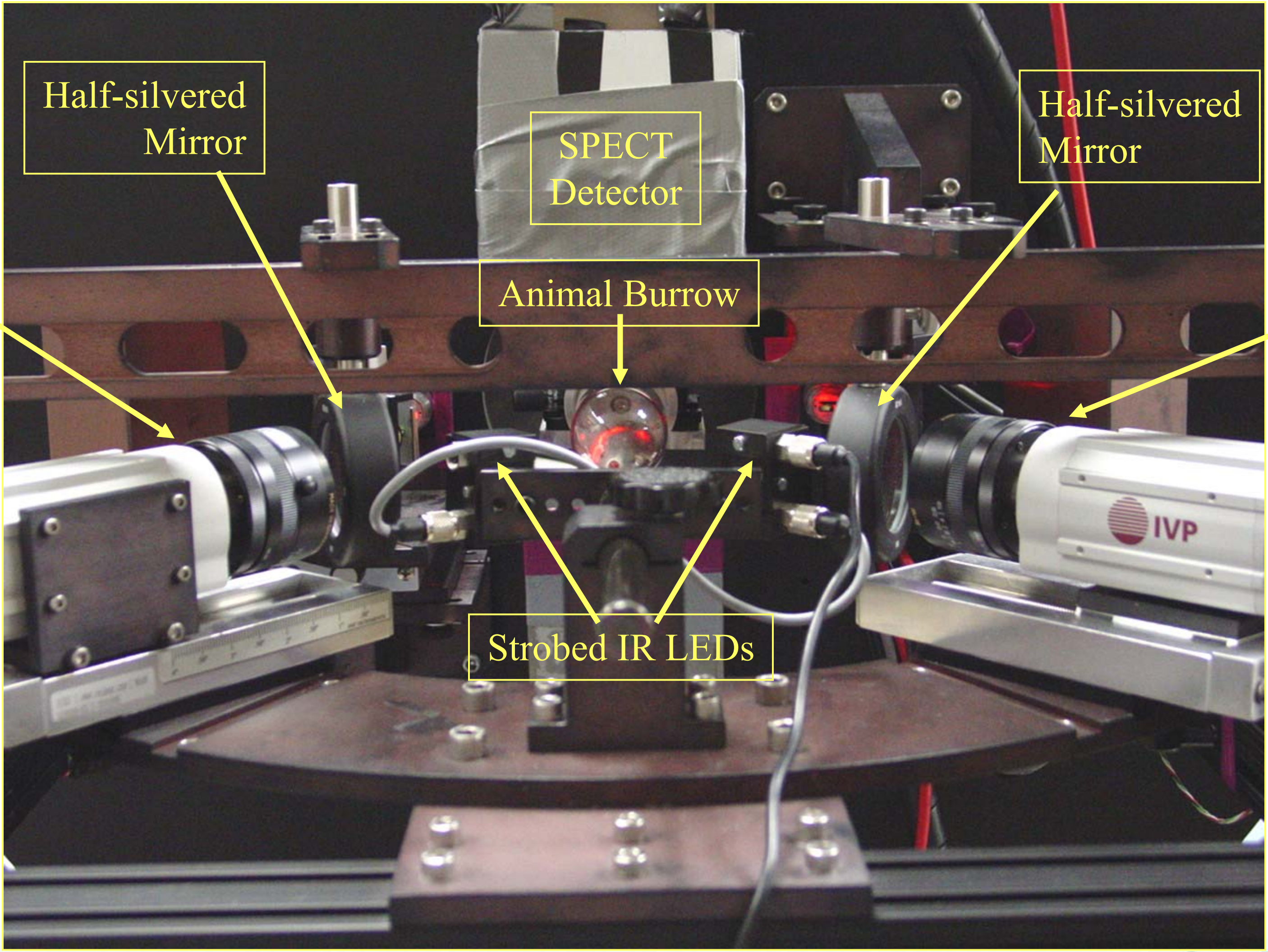
Real-Time Animal Tracking System

- Develop optical-based, non-contact animal tracking system
- Track animal with minimal stress to animal
- Calculate pose (x,y,z,roll,pitch,yaw) of animal to sub-mm accuracy
- Track animal in real-time
- Start with extrinsic marker approach for head
- Move to other body regions (thorax, abdomen) using surface-based approach

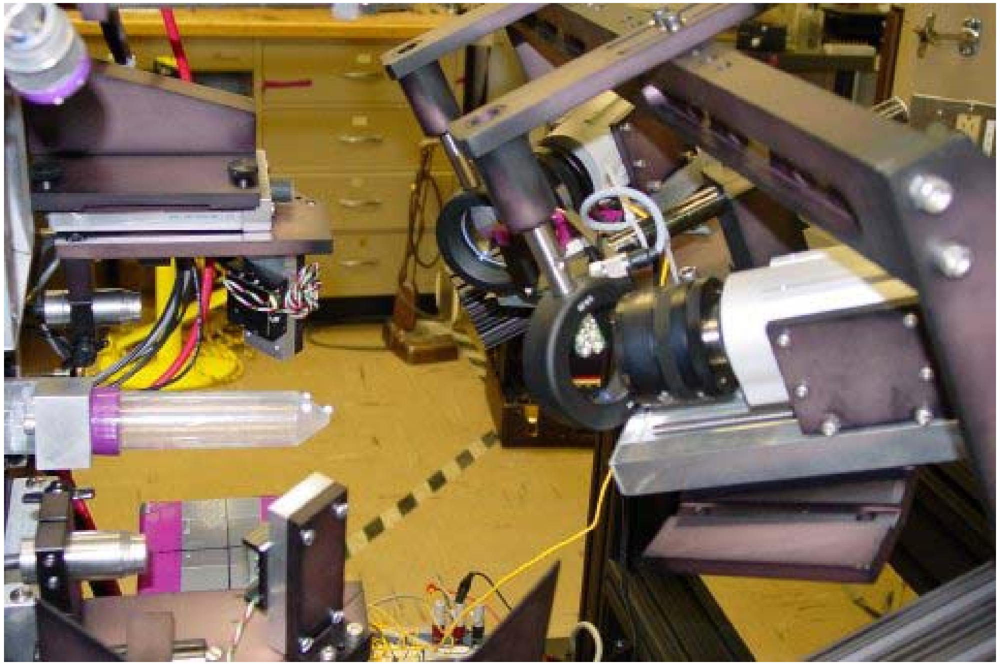
Animal Tracking System
Image Acquisition/Optics Layout



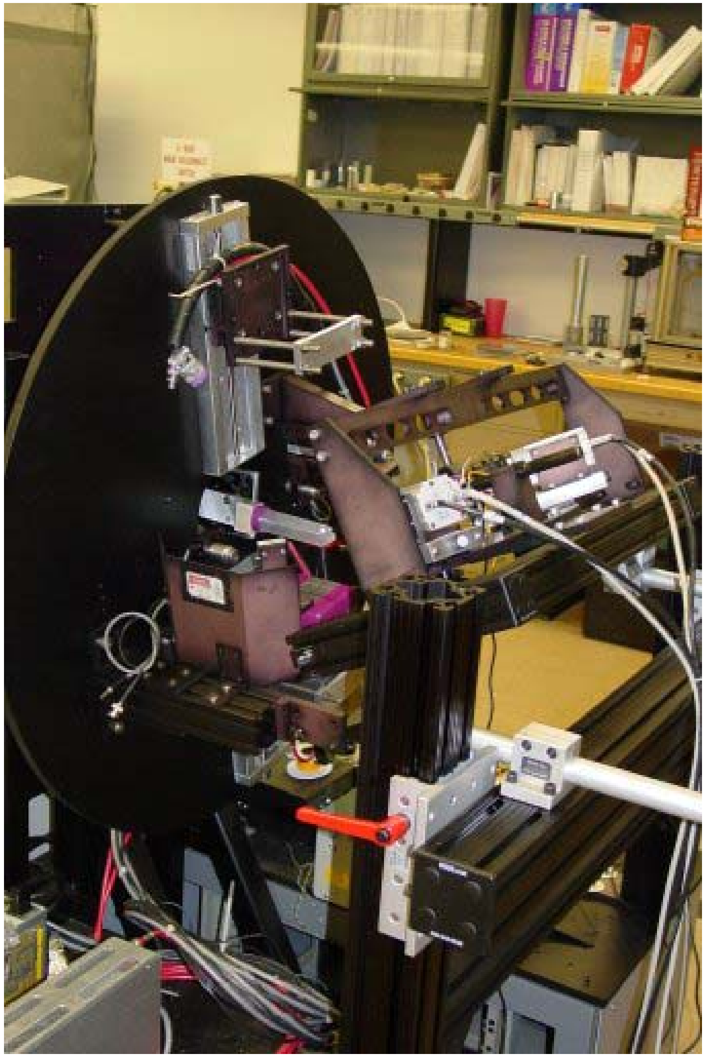
Tracking System Hardware



Tracking System Hardware



Side View



Rotating Gantry View

IR Reflector Tracking:
Retro-reflective Markers on Head

- Markers attached with "super-glue" technology while animal under anesthesia
- Typical mouse "grooms" reflectors for 10-15 minutes after awakening
- Mice eventually revert to normal behavior (5 animals tested so far)

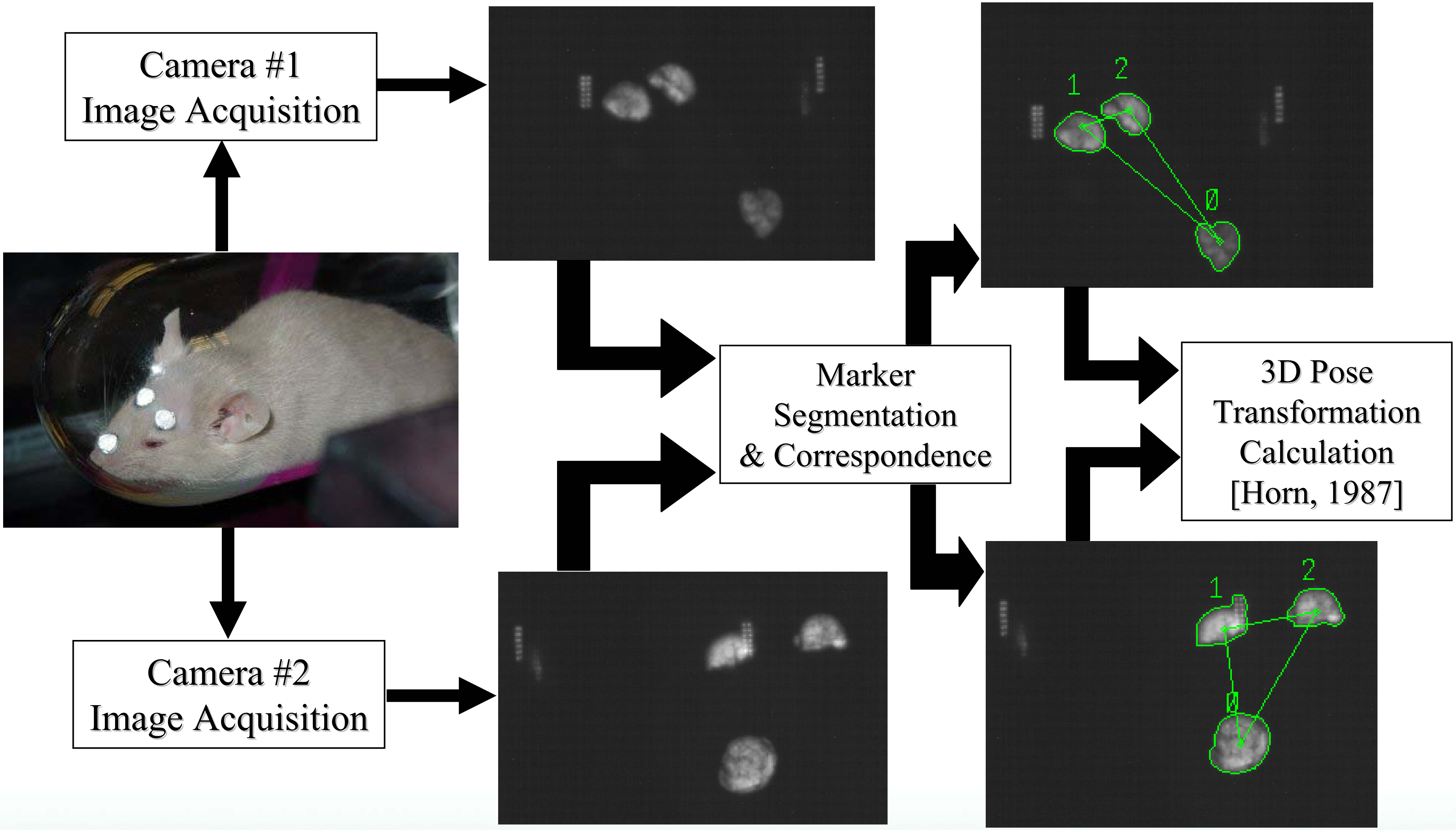
(no flash)

(with flash)

IR Reflector Tracking:
Animal Burrow Design Progress

- **First Trial: AMTIR (amorphous material transmitting infrared radiation)**
  - Opaque up to 700 nm
  - Tube fabrication problems:
    - Not viscous enough for glass-blowing
    - Too brittle to machine
  - Injection mold
- **Second Trial: Clear Glass Tube**
  - Fabricated at ORNL
  - Plans for CVD anti-reflective coating
  - Scanning in the dark to calm animal

IR Reflector Tracking:
Extrinsic Marker-based Pose Measurement



IR Reflector Tracking:
Extrinsic Marker-based Calibration Software

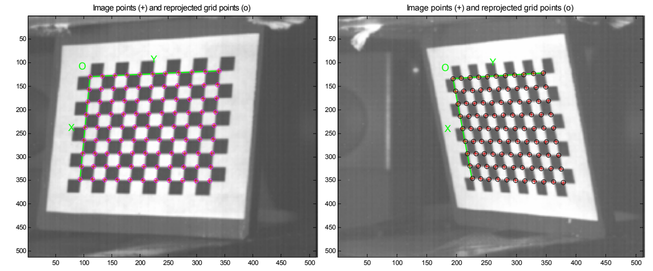
- **Intrinsic camera calibration**
  - **focal lengths, α, β**
  - **optical center, u_0, v_0**
  - **axes skew, γ**
  - **radial and tangential distortions (lens, burrow)**

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \mathbf{A}\begin{bmatrix}\mathbf{R} & \mathbf{t}\end{bmatrix}\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \qquad \mathbf{A} = \begin{bmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix}$$

- **Extrinsic camera calibration: relative pose of object and camera coordinate systems (rotation matrix, *R*, and translation vector, *t*)**

$$x_C = R x_W + t$$

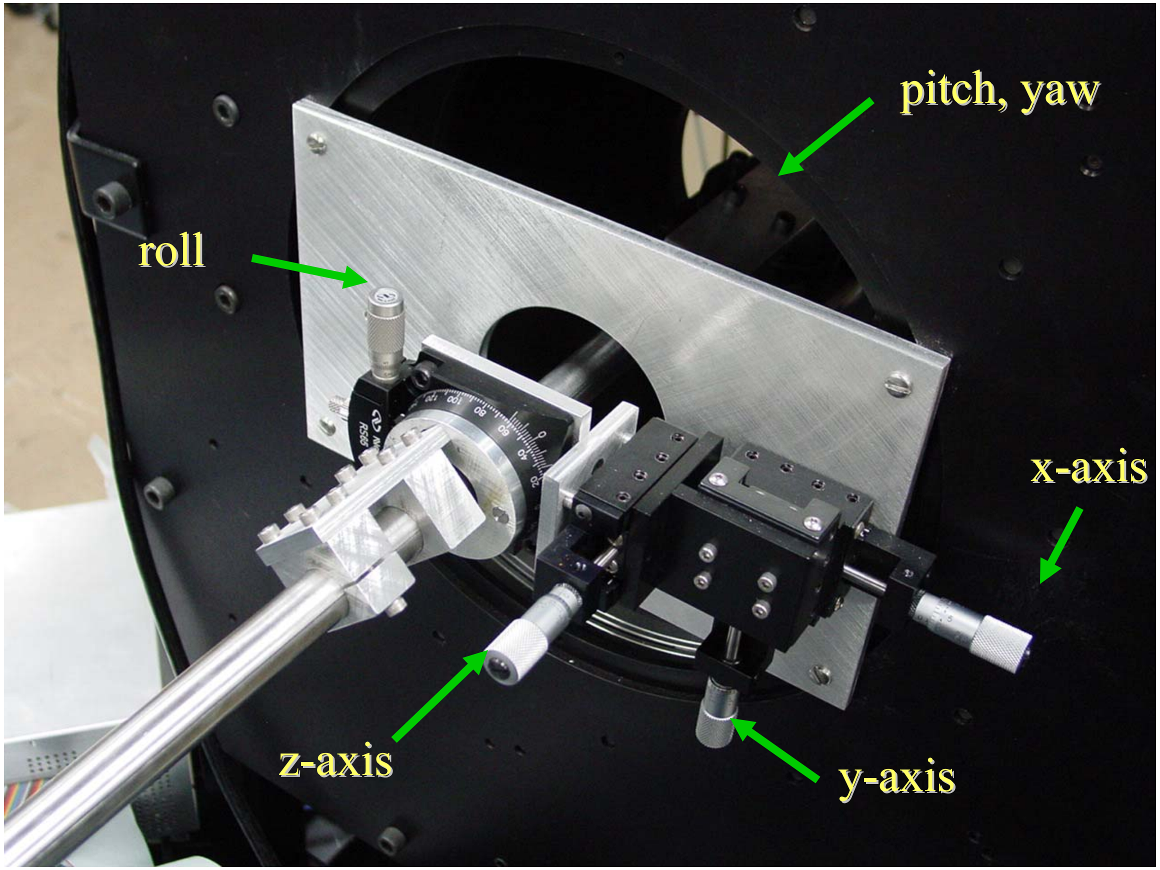
- **Multiple images of calibration target acquired and grid is auto-segmented**
- **Nonlinear optimization algorithm calculates calibration parameters [Zhang, 1998]**
- **Fundamental matrix, *F*, used for assigning correspondence between camera points [Hartley, 2000], [Faugeras, 2001]**



$$x'^T F x = 0$$

IR Reflector Tracking:
Tracking Performance Validation Hardware

Back of SPECT Gantry



All 6 degrees-of-freedom are manually adjustable

IR Reflector Tracking:
Performance Measurements

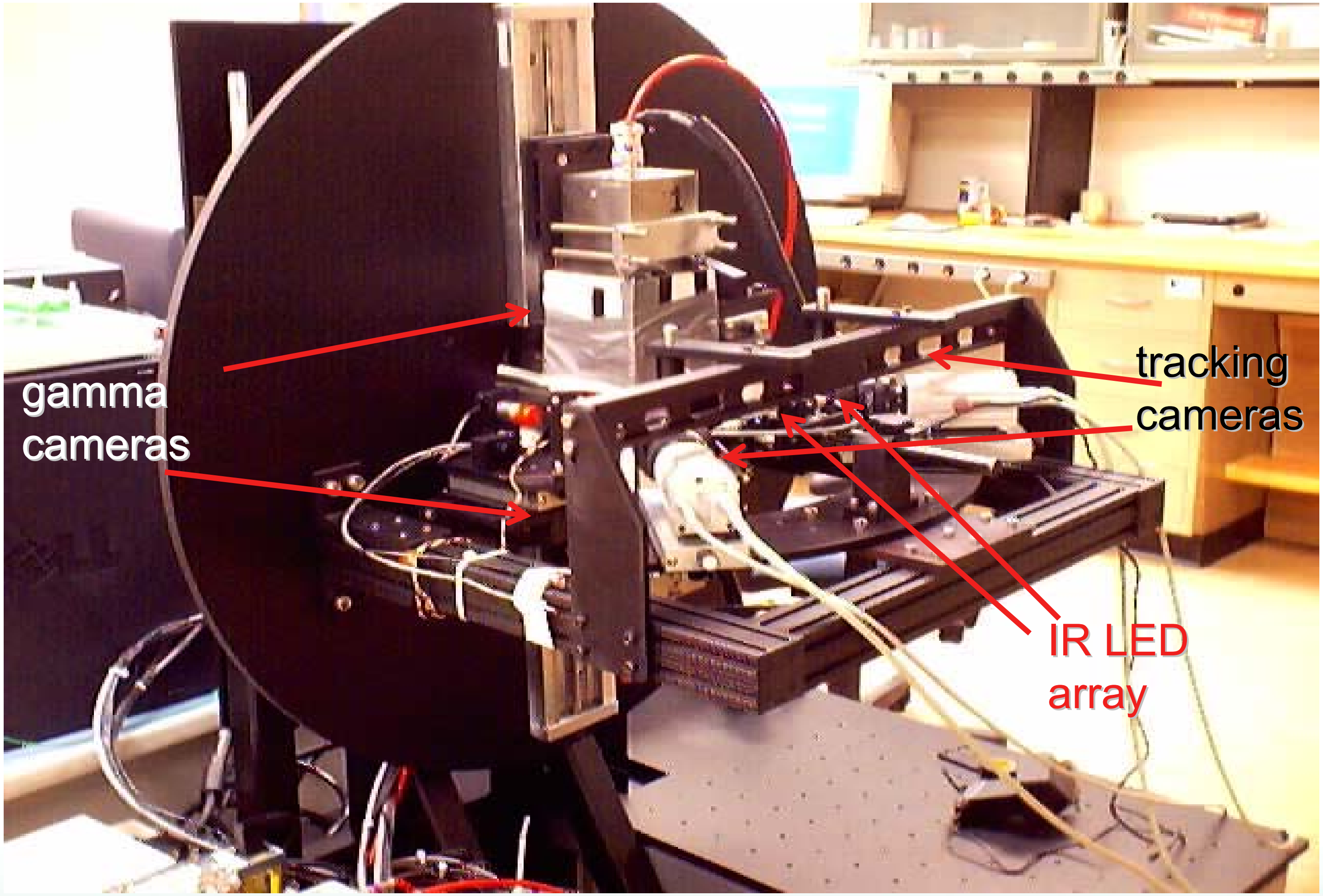
Accuracy (Test Phantom):

	Actual	Measured
Translation (mm)		
x (transaxial)	**10**	**10.02**
y (transaxial)	**10**	**9.94**
z (axial)	**12.7**	**12.73**
Orientation (degrees)		
roll	**6**	**5.6**
pitch	**5**	**5.5**
yaw	**6**	**5.8**

Repeatability: 0.002 mm and 0.03 degrees

Frequency: 12 pose measurements per second

Laser Profile Tracking:
SPECT System Setup



Summary and Future Goals

Summary

- **Discussed need for non-anesthetized live animal SPECT imaging**
- **Presented IR strobe with reflector tracking technique**

Future Work

- **Simultaneous SPECT and tracking studies**
- **Remapping of SPECT events based on animal position prior to image reconstruction**

References

[1] Z. Zhang, “A flexible new technique for camera calibration,” MSR-TR-98-71, Microsoft Research, Microsoft Corp., Redmond, WA, December 2, 1998.

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[3] O. Faugeras and Q-T. Luong, The Geometry of Multiple Images, Cambridge: The MIT Press, 2001.

[4] B. Horn, "Closed-form solution of absolute orientation using unit quaternions," Journal of the Optical Society of America, 4, pp. 629-642, April 1987.