From Health (Biomedical Chaos) and Grid (Decomposition and Integration) to HealthGrid

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Computation Institute of the University of Chicago and Argonne National Laboratory

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From Here:

Academic Medical Center

Biomedical Research

Networking

Clinical Epidemiology

Data

Algorithms

Applications

Post-Genomic Era

Medicine

Processors

Collaboration

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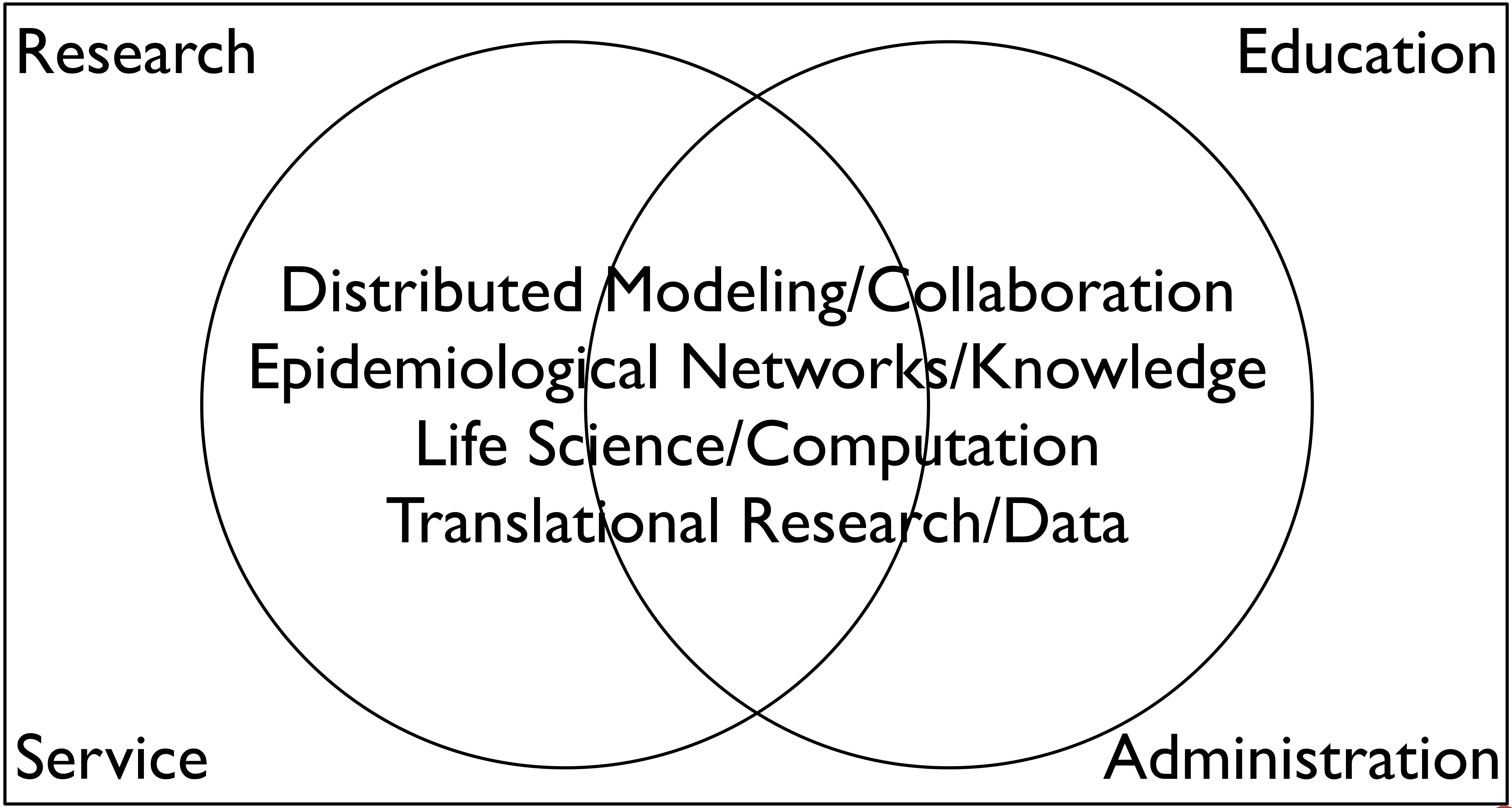
To Here:



Health - HealthGrid - Grid

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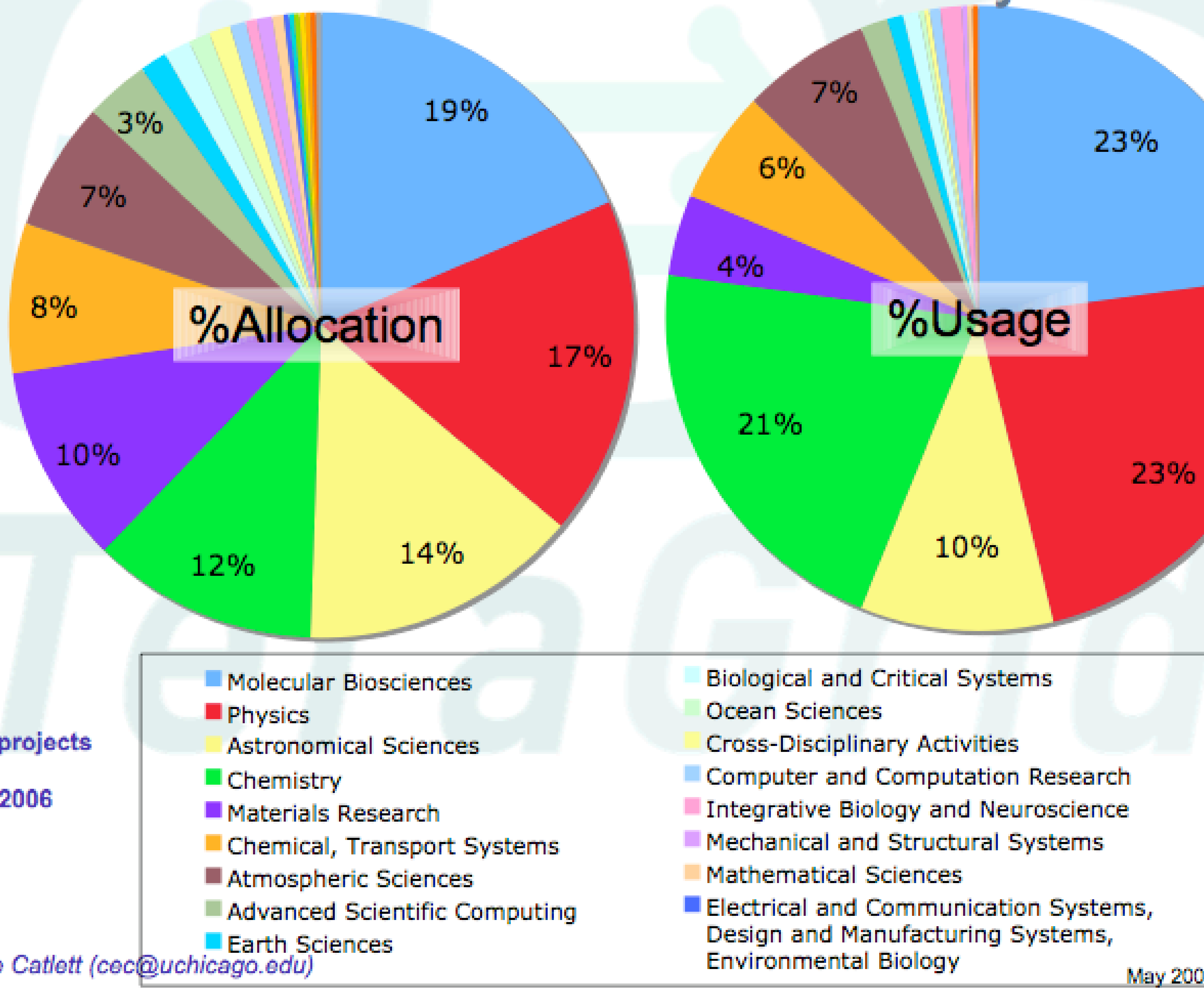
(Health)Grids Defined - (www.healthgrid.org)

- Computational Grids
  - virtual supercomputers, dynamically aggregating the power of a large number of individual computers in order to provide platforms for advanced applications
- Data Grids/Information and Knowledge Grids
  - focus on the sharing of vast quantities of data
  - extended to support data categorization, information discovery, ontologies, and knowledge sharing
- Collaborative Grids
  - establish virtual environments, enabling geographically dispersed individuals or groups to cooperate or remote control of equipment, sensors, and instruments

TeraGrid User Community



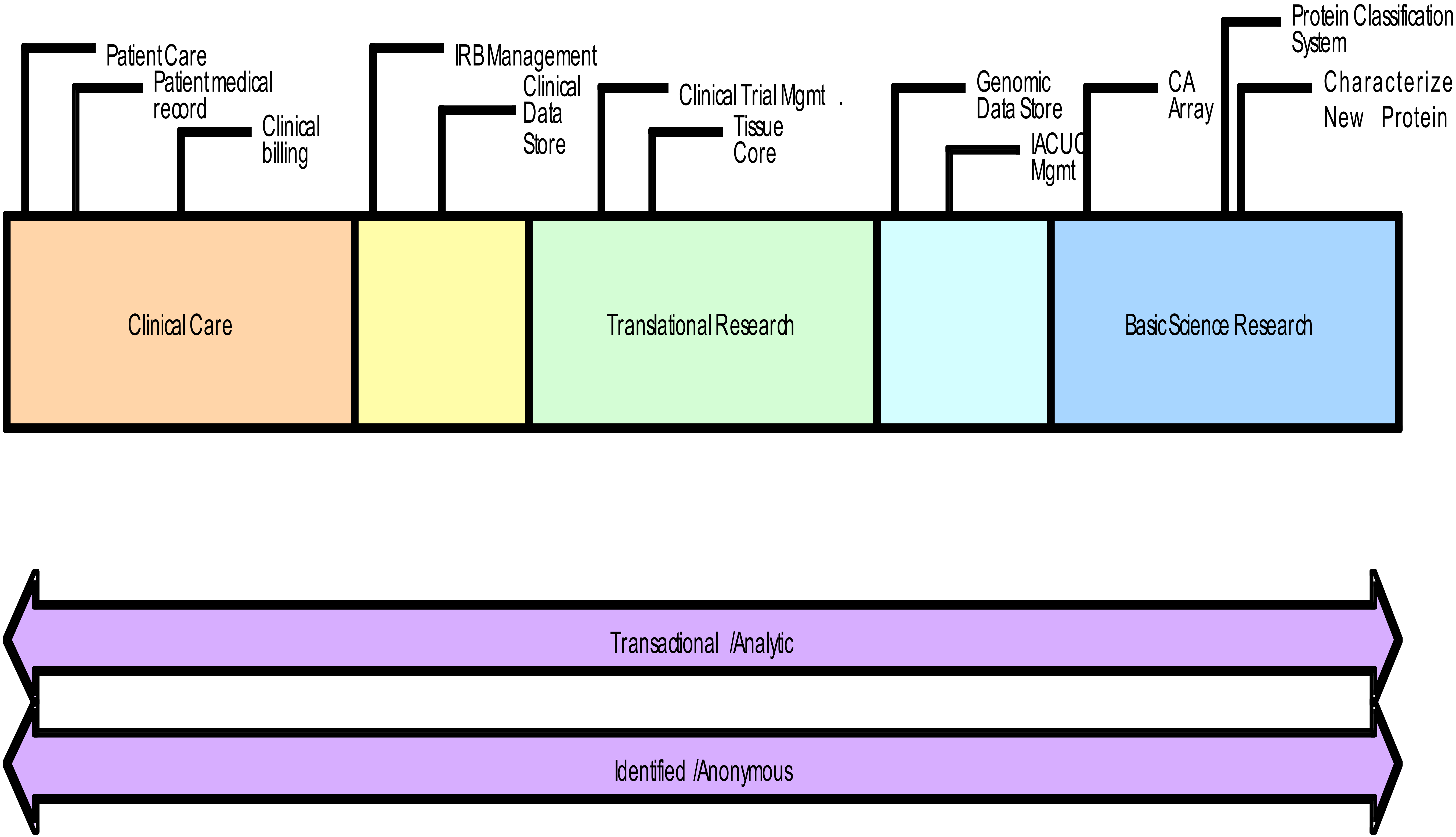
1000 projects as of April 2006

Charlie Catlett (cec@uchicago.edu)

May 2006

TeraGrid

Biomedical Data Stores



ACCESS GRID™

www.accessgrid.org

The Access Grid™ is an ensemble of resources including multimedia large-format displays, presentation and interactive environments, and interfaces to Grid middleware and to visualization environments.

These resources are used to support group-to-group interactions across the Grid. For example, the Access Grid (AG) is used for large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials, and training.

Small Science	Big Science
Focused Experimental	High Throughput
Single PI/Laboratory	Multiple Investigators
Hypothesis Driven	Simulation/Analysis
Small Dollars	Big Dollars
Biology	Systems Biology
Validation	Discovery
Publications	Service Oriented
Proprietary/One Time	Open/Standards

Value Both - Advancement Requires Both

Small Medicine	Big Medicine
Unique Care Plans	High Throughput
Practitioner	Team
Hypothesis Driven	Evidence Based
Small Dollars	Big Dollars
Healthcare System	Systems Medicine
Validation	Probability
Outcome Oriented	Service Oriented
Medical Record	Open Standards/Data

Value Both - Advancement Requires Both

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www.ci.uchicago.edu

Addressing the most **challenging** problems arising in the use of **strategic** computation and **communications** across a broad spectrum of **intellectual** activities.

Two Perspectives on System-Level Problems

- System-level problems *require* **integration**
  - Of expertise
  - Of data sources ("data deluge")
  - Of component models
  - Of experimental modalities
  - Of computing systems
- Internet *enables* **decomposition**
  - "When the network is as fast as the computer's internal links, the machine disintegrates across the net into a set of special purpose appliances" (George Gilder)

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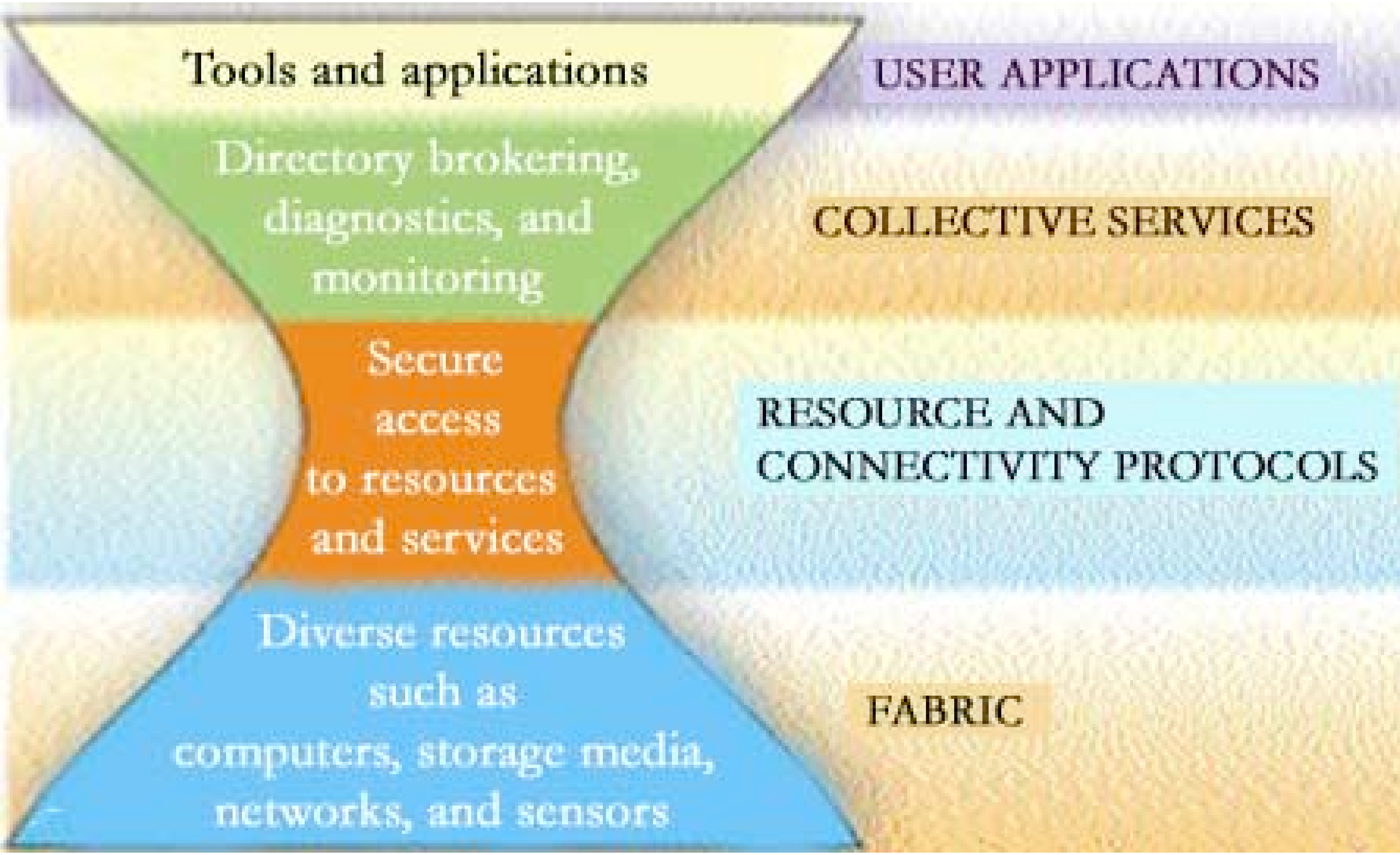
Enabling Integration & Decomposition

- **Integration** demands new tools & thinking
  - *Information technology*: conventions & tools for accessing remote resources
  - *Policy*: social, (inter-)institutional, legal
  - *Domain*: methodologies & tools
- **Decomposition** demands specialization
  - Resource consumers & providers
  - Types of expertise
  - Types of resource
  - Numerous technical *and* policy issues



The Grid: A New Infrastructure for 21st Century Science
Ian Foster
Physics Today - February 2002

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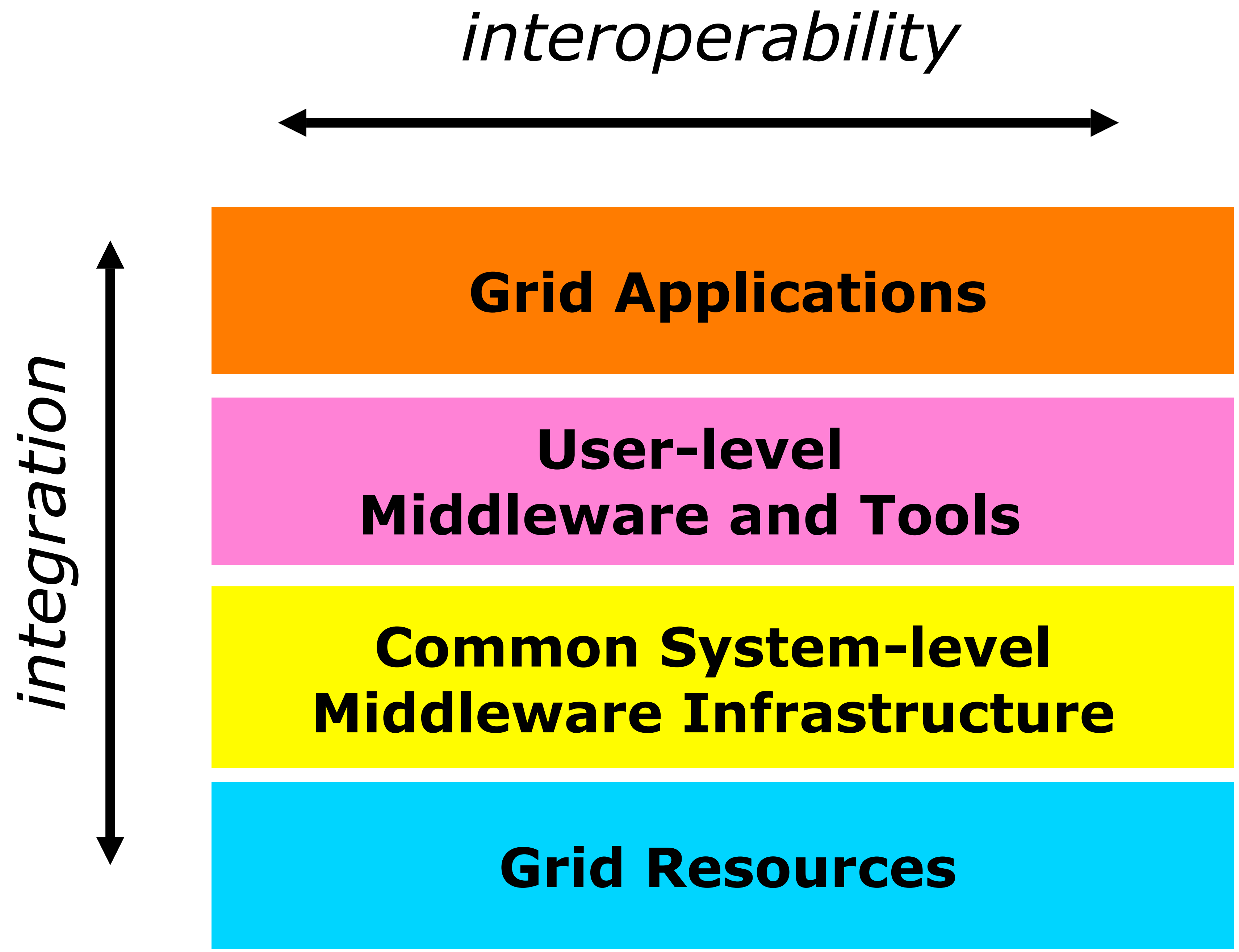
Middleware & Standards



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Science 6 May 2005: Service-Oriented Science

Ian Foster

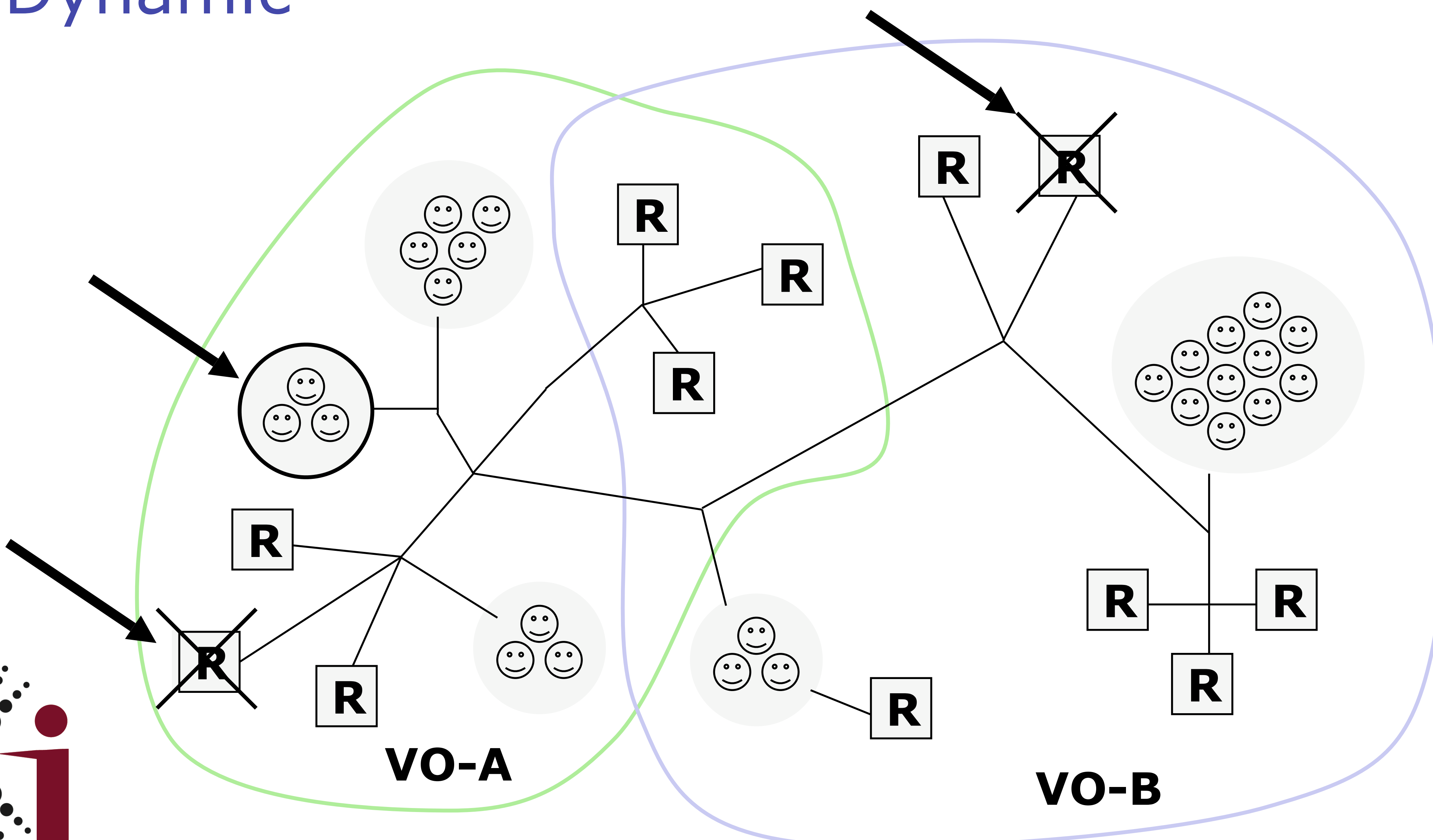
…. So-called service-oriented architectures define standard interfaces and protocols that allow developers to encapsulate information tools. … ; previously manual data-processing and analysis tasks can be automated by having services access services. … . Grid technologies can accelerate the development and adoption of service-oriented science by enabling a separation of concerns between discipline-specific content and domain-independent software and hardware infrastructure.

Major Players in Defining, Creating, & Applying Grid

- Application scientists
- Service providers
- Middleware providers
- Resource providers
- Communities (aka "virtual organizations")
- Institutions
- Standards organizations
- Social scientists?
- Lawyers?

Virtual Organizations

- Distributed resources and people
- Linked by networks, crossing admin domains
- Sharing resources, common goals
- Dynamic



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Grid Summary

- Two dimensions to Grid
  - Integration of expertise & resources
  - Decomposition of function & roles
- Grid infrastructure is the key enabler
  - Service-oriented architecture
  - Open source software & open standards
- Vibrant international community
  - Developers, deployers, applications
- Technology, sociology, & policy challenges

Advanced Biomedical Collaboration Testbed

Jonathan C. SILVERSTEIN, Stephen SMALL, Michael SMITH,
Michael E. PAPKA
Departments of Surgery, Anesthesia, Radiology, University of Chicago
Computation Institute, University of Chicago/Argonne National Laboratory
General Devices
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THE UNIVERSITY OF CHICAGO

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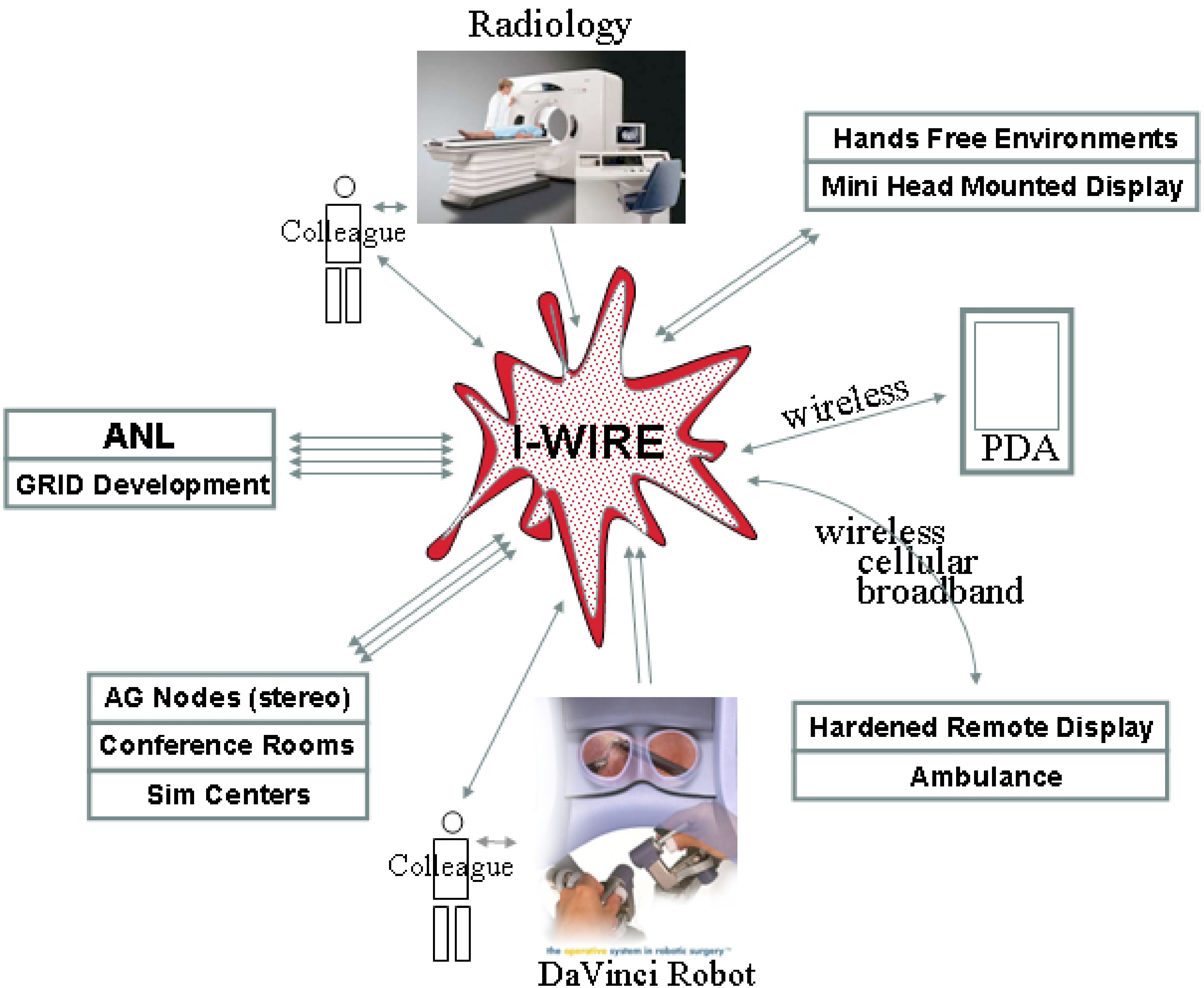
Argonne NATIONAL LABORATORY

Funding

- National Library of Medicine / National Institutes of Health
- University of Chicago and University of Chicago Hospitals
- The Searle Funds at The Chicago Community Trust
- Northwestern University, University of Illinois at Chicago
- Access Grid Team funded by DOE, NSF, and FusionGrid

Collaboration in biomedicine versus Telemedicine

- Collaboration involves professionals in more than one location working together whether or not a patient is present
  - typically involves a substantial degree of presence or immersion
- Tele-medicine typically involves data transmission directly from a patient to a professional
  - tele-medicine typically involves a minimal set of data sources and may not necessarily be synchronous.



Radiology
Hands Free Environments
Mini Head Mounted Display
Colleague
PDA
wireless
ANL
GRID Development
I-WIRE
wireless
cellular
broadband
AG Nodes (stereo)
Conference Rooms
Sim Centers
Hardened Remote Display
Ambulance
Colleague
DaVinci Robot

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Application Sharing

- The Access Grid software includes facilities for sharing applications with other participants in the Venue
- Venue file storage is used to exchange file-based data among shared application participants
- Raw Venue data storage can be used to maintain application state
- Venue event channels are used to distribute changes to application state to participants
- Access to shared applications is restricted to Venue participants, and can be further restricted

CBC

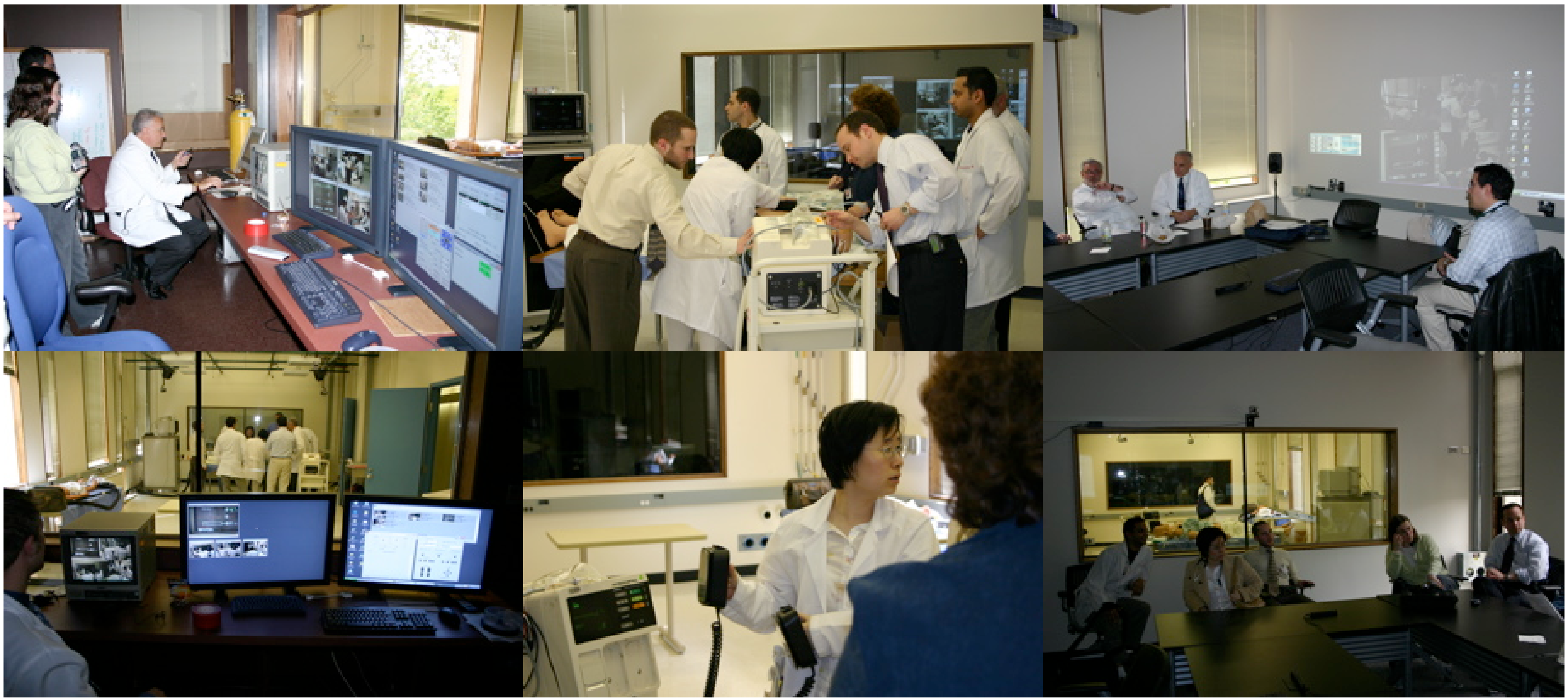
The Chicago Biomedical Consortium

The University of Chicago
University of Illinois at Chicago
Northwestern University

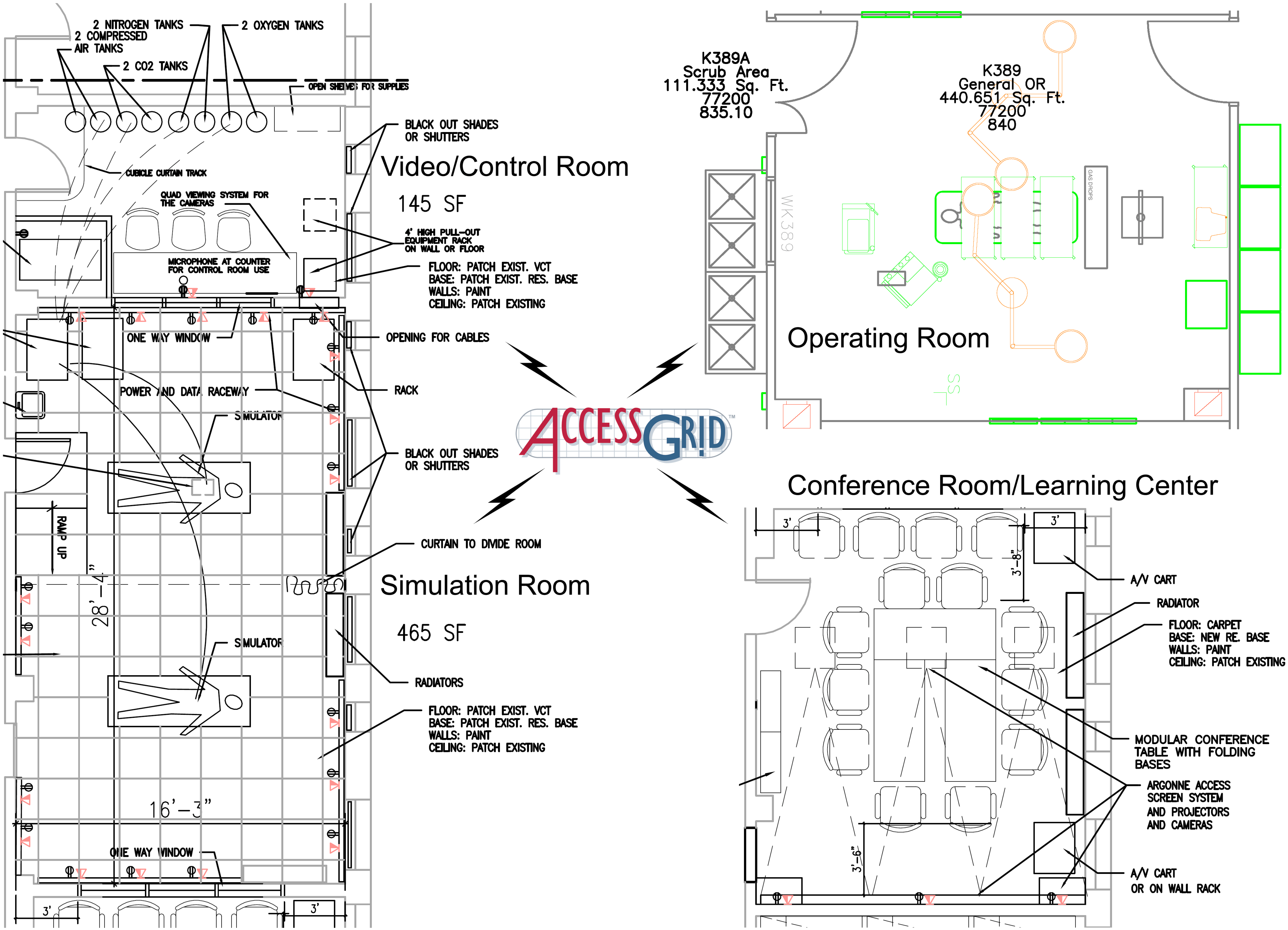
The mission of the Chicago Biomedical Consortium is to stimulate and sustain research at the frontiers of biomedicine through ongoing collaboration and exchange among scientists in the Chicago area. Established by scientists at Northwestern University, the University of Chicago, and the University of Illinois at Chicago, and endorsed by the three universities, it will:

- Enable collaborative and interdisciplinary research that is beyond the range of an individual investigator or a single institution,
- Stimulate research and training programs that bridge institutional boundaries,
- Recruit and retain a strong cadre of biomedical leaders and researchers in Chicago,
- Promote the development of the biomedical industry in Chicago through partnerships with corporations, joint mentorship of researchers, and commercialization of discoveries,
- Execute a plan capable of improving the health of citizens of Chicago and beyond.

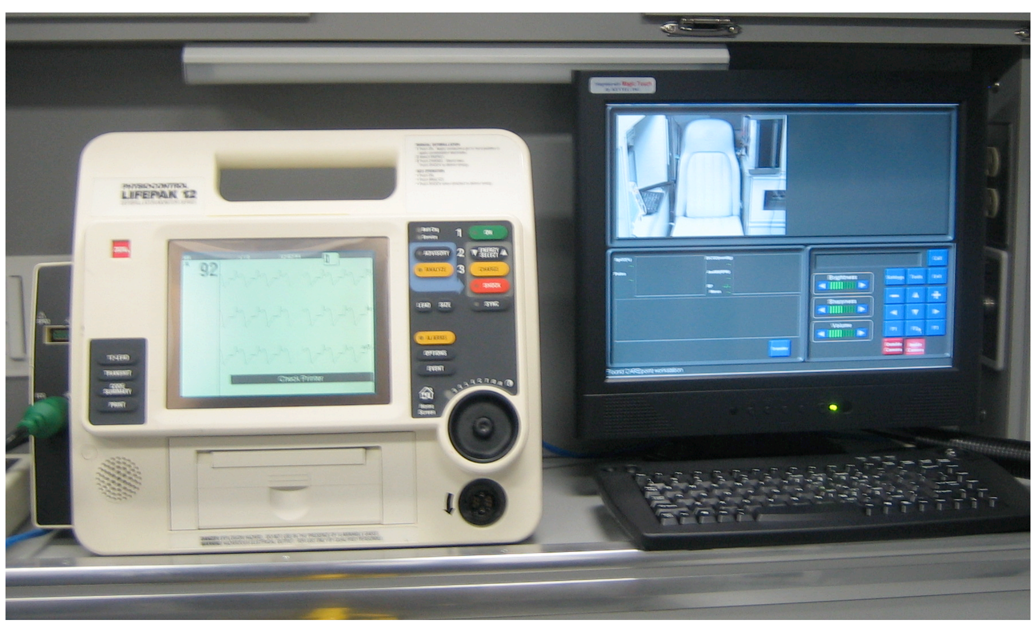
Immersive Team Training through Simulation



University of Chicago Minimally Invasive Training Facility



EMS Real-Time Communication

General Devices


CAREpoint
92
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38
15
72
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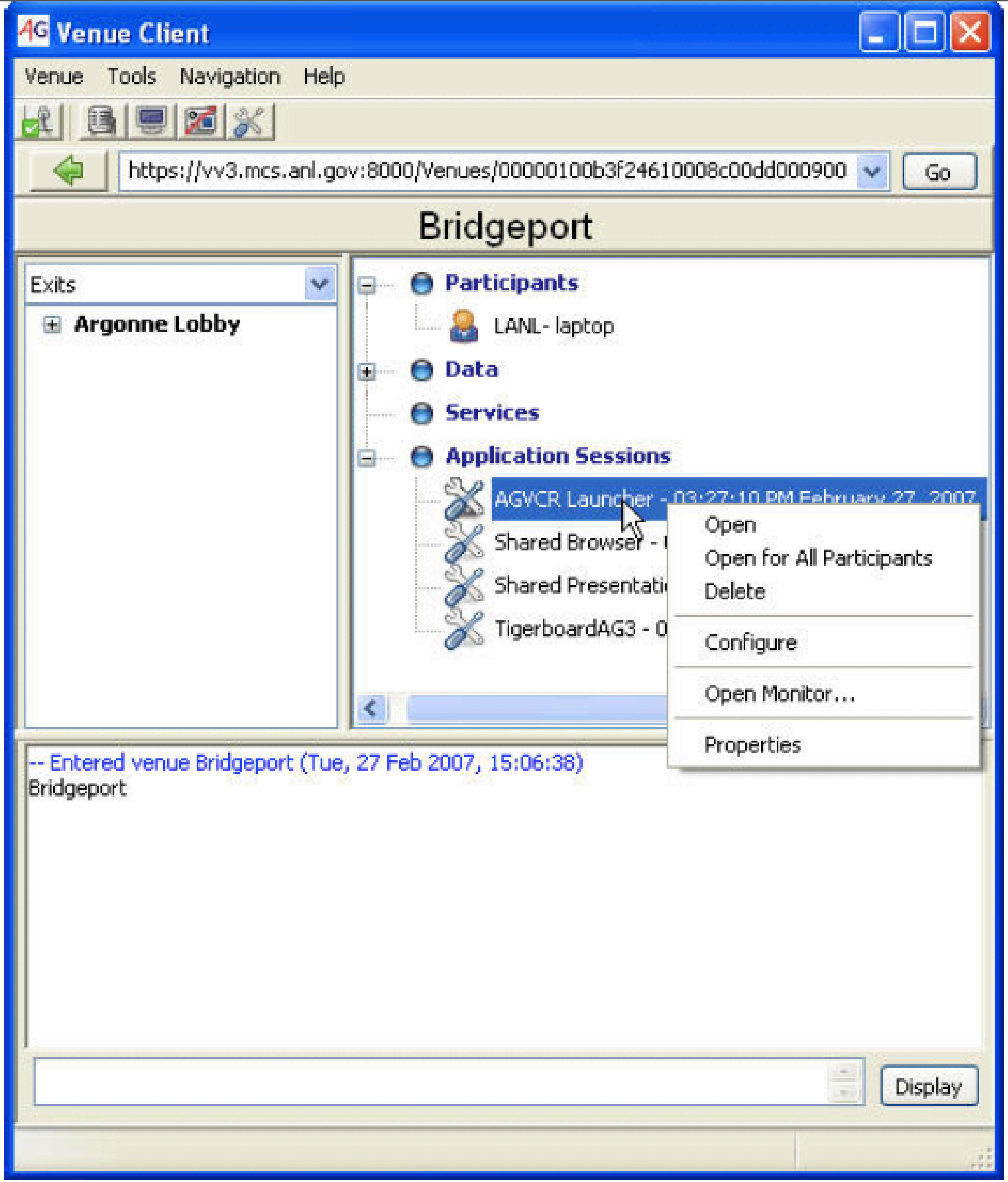
GENERAL DEVICES
CAREpoint

Tele-Volume Rendering - Scenario

- Shared Distributed Volume Radiology Drivers
  - Complex care among multiple teams
  - Massive datasets now being sampled rather than being used in entirety
  - Complete virtualization is possible
  - Desire for subtle illustration in the hands of Physicians, not just techs
- Surgical Rehearsal

Challenges in Radiological Visualization

- Rapid expansion of knowledge and tools
  - Data so voluminous interpretation requires advanced visualization techniques - e.g. New Philips 64-slice CT - DICOM data sets
  - Hi-res full body scan consists of 3000-5000 2D axial slices @ 512^2 (or more) pixels per slice.
- Limited availability of experts
  - Increasingly specialized procedures require surgeon direct access to visualization tools and colleagues in real time to generate detailed patient-specific visualizations
  - Such advanced visualization tools must, at a minimum, mimic the tools available on proprietary radiological workstations (e.g. GE Medical, Toshiba, Philips etc).
- Visualization technically complicated
  - Multiple locations for acquisition, pre-processing, and display
  - "larger than desktop" visualization engines needed (i.e. clusters)
- Solution: Application of Access Grid and other Grid technologies


Venue Client
Venue
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Help
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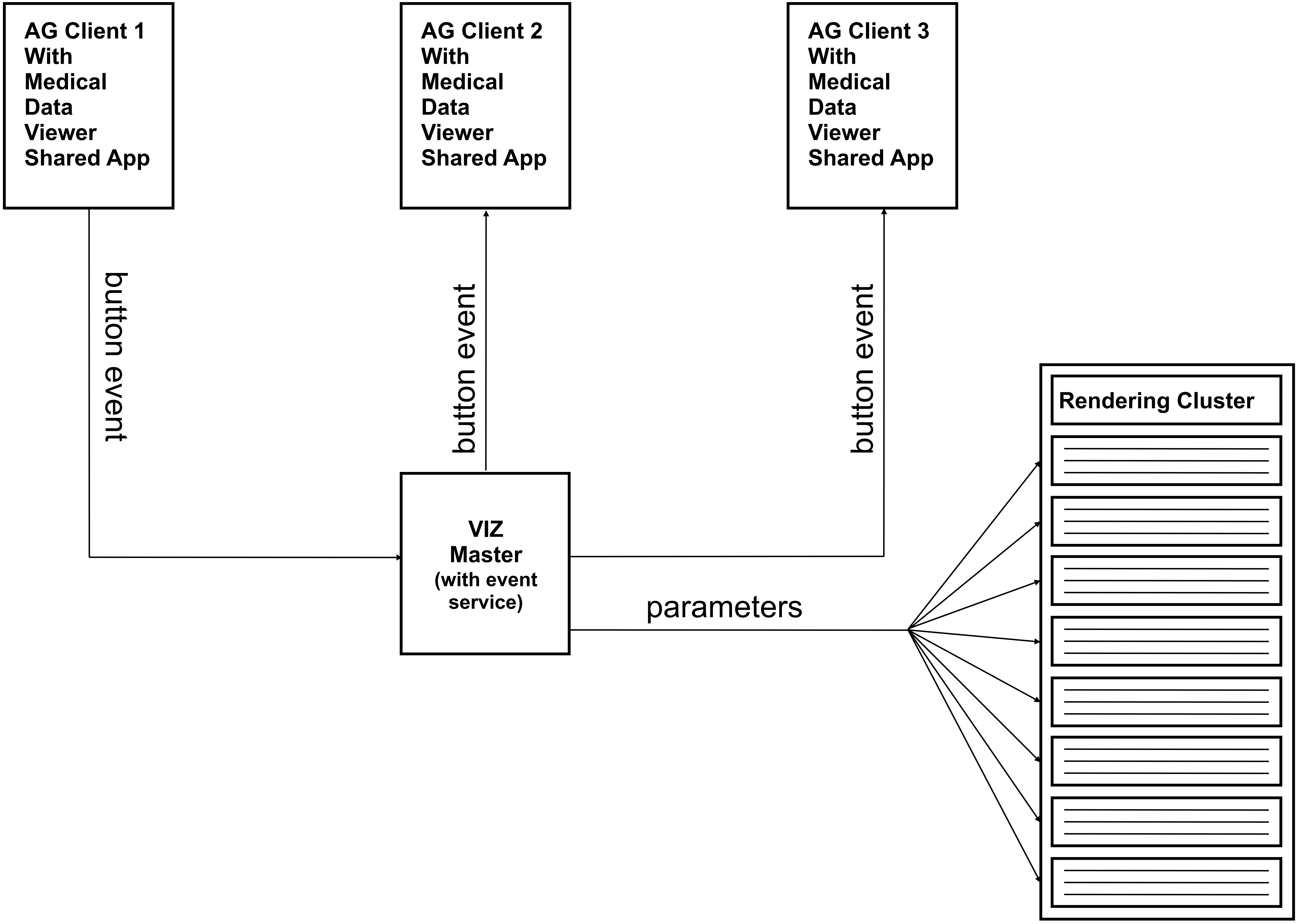
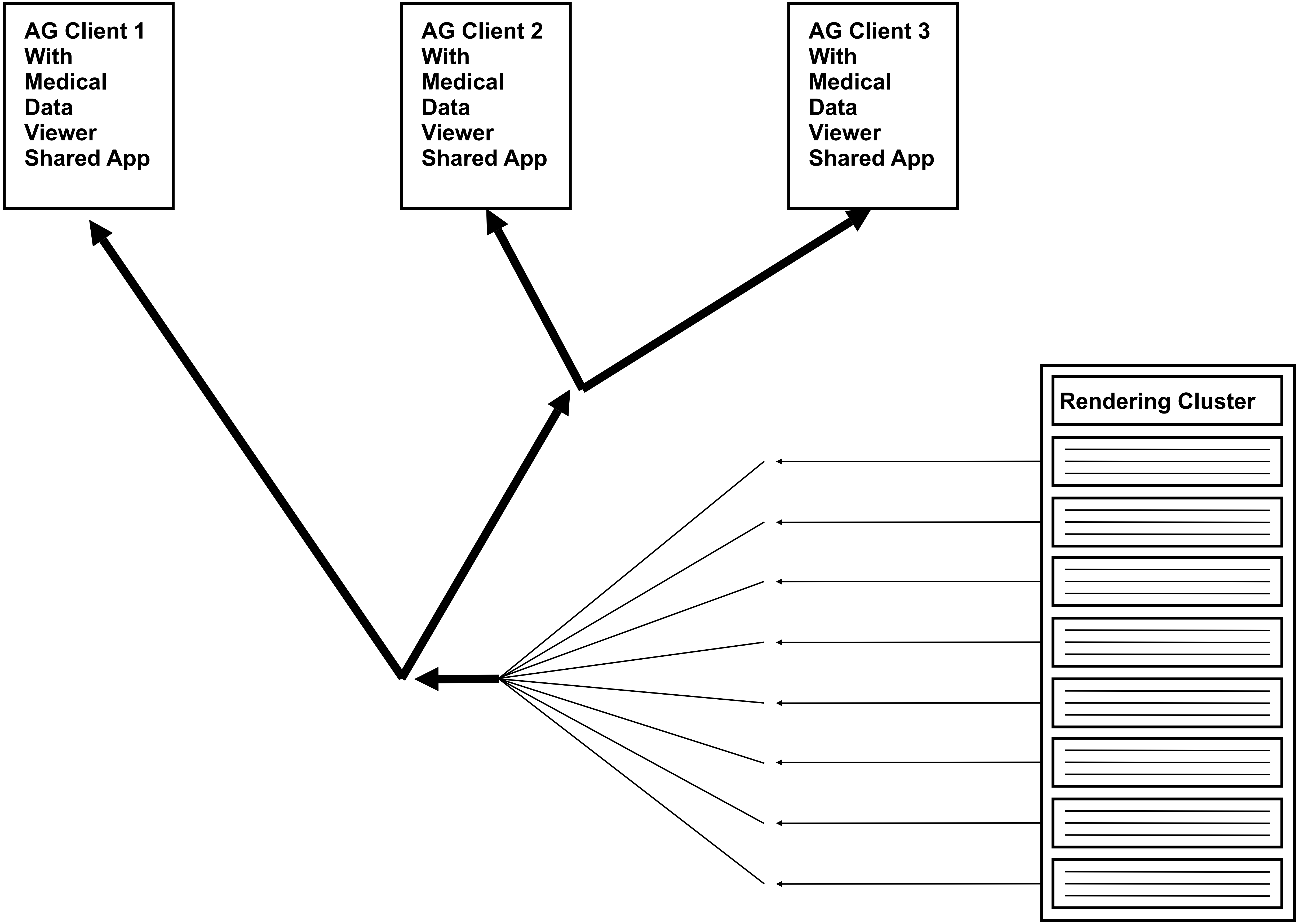
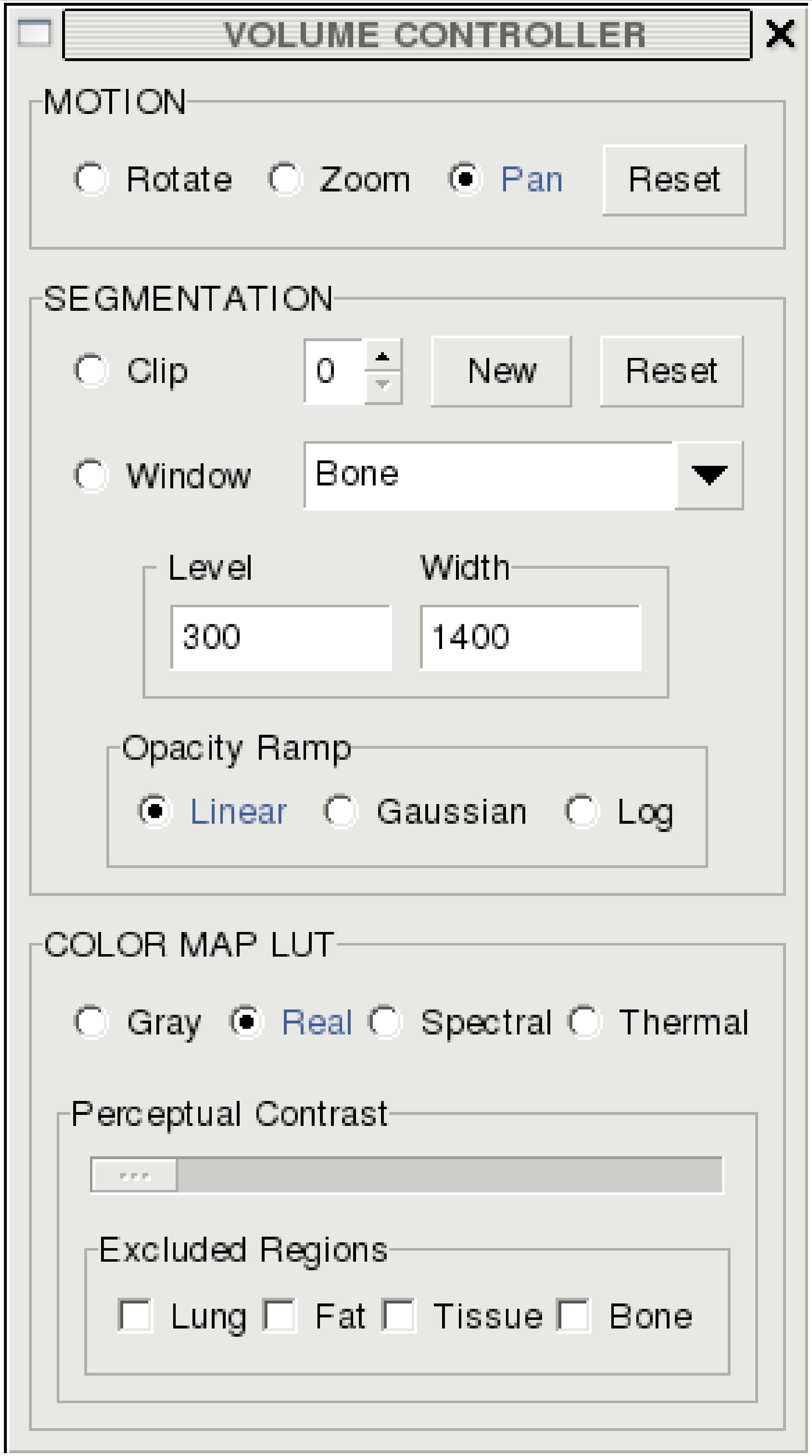
Bridgeport
Exits
Argonne Lobby
Participants
LANL- laptop
Data
Services
Application Sessions
AGVCR Launcher - 03:27:10 PM February 27, 2007
Shared Browser -
Shared Presentati
TigerboardAG3 - 0
Open
Open for All Participants
Delete
Configure
Open Monitor...
Properties
-- Entered venue Bridgeport (Tue, 27 Feb 2007, 15:06:38)
Bridgeport
Display


AG Client 1 With Medical Data Viewer Shared App
AG Client 2 With Medical Data Viewer Shared App
AG Client 3 With Medical Data Viewer Shared App
button event
button event
button event
VIZ Master (with event service)
parameters
Rendering Cluster


AG Client 1 With Medical Data Viewer Shared App
AG Client 2 With Medical Data Viewer Shared App
AG Client 3 With Medical Data Viewer Shared App
Rendering Cluster

Color Atlas of Anatomy
Atlas of Human Anatomy


VOLUME CONTROLLER
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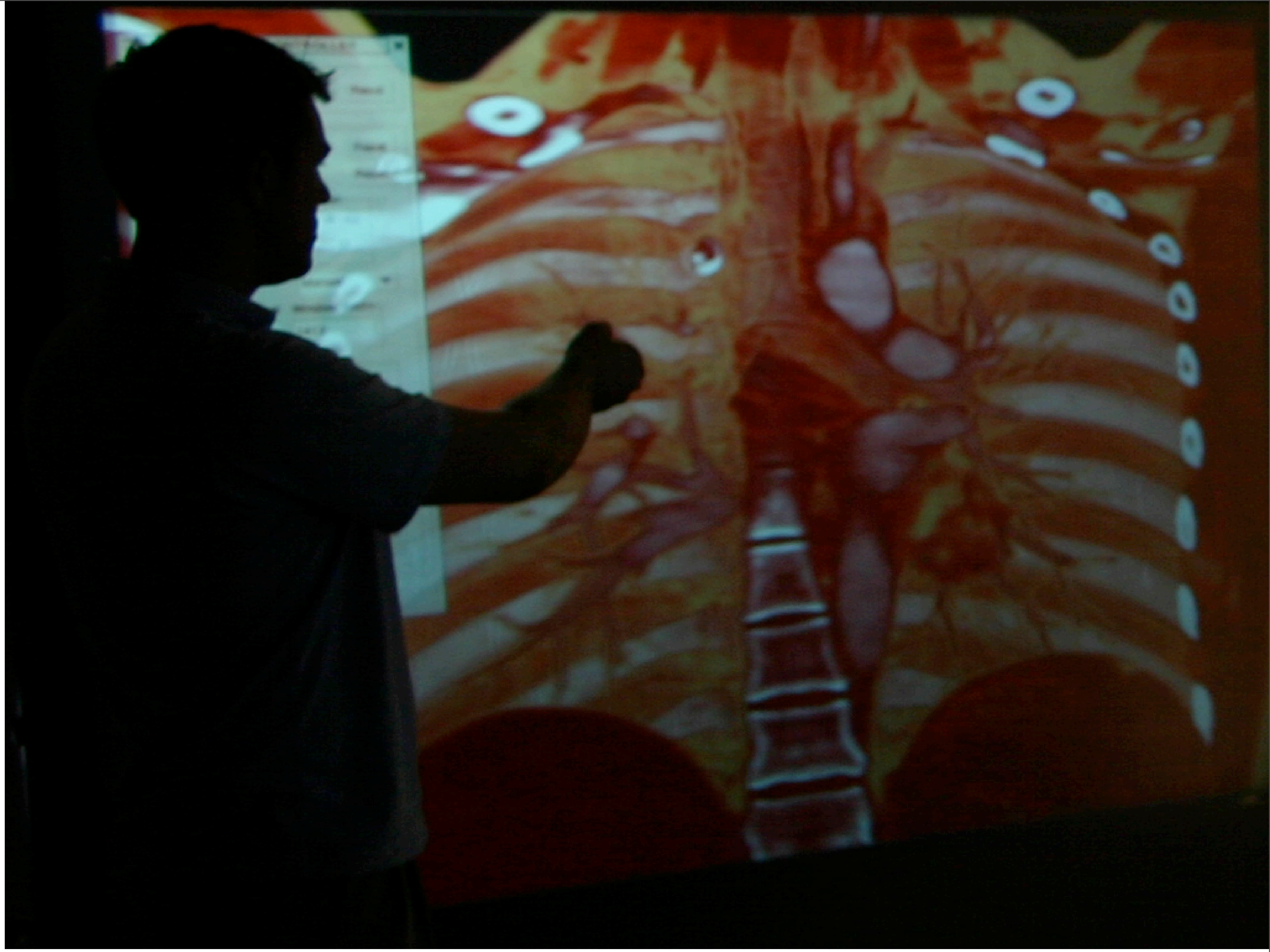
Opacity Ramp
Linear
Gaussian
Log
COLOR MAP LUT
Gray
Real
Spectral
Thermal
Perceptual Contrast
Excluded Regions
Lung
Fat
Tissue
Bone

Virtual Reality (VR) systems are enablers.

This photograph shows a virtual reality system built collaboratively by Surgery, Radiology, and Computation Institute. It loads clinical data instantly into a high-performance graphics cluster for direct manipulation in larger-than-life stereo visualization for surgery planning and anatomic education.



VR surgical simulation:

- ✓Enables trainees to see many variations that they would take years to accumulate using the current "random exposure" method
- ✓Enables repeated, independent training, with feedback, to specific criterion performance, thereby ensuring patient safety
- ✓Enables precise pre-planning for personalized care with predictable outcome (improving safety and making possible procedures previously considered "too risky")

Immersive Virtual Anatomy Course using a Cluster of Volume Visualization Machines and Passive Stereo

Jonathan C. SILVERSTEIN[1,2], Colin WALSH[1], Fred DECH[1], Eric OLSON[2], Michael E. PAPKA[2], Nigel PARSAD[1], Rick STEVENS[2]

[1]Department of Surgery, University of Chicago, Chicago IL, USA

[2] Computation Institute, University of Chicago/Argonne National Laboratory

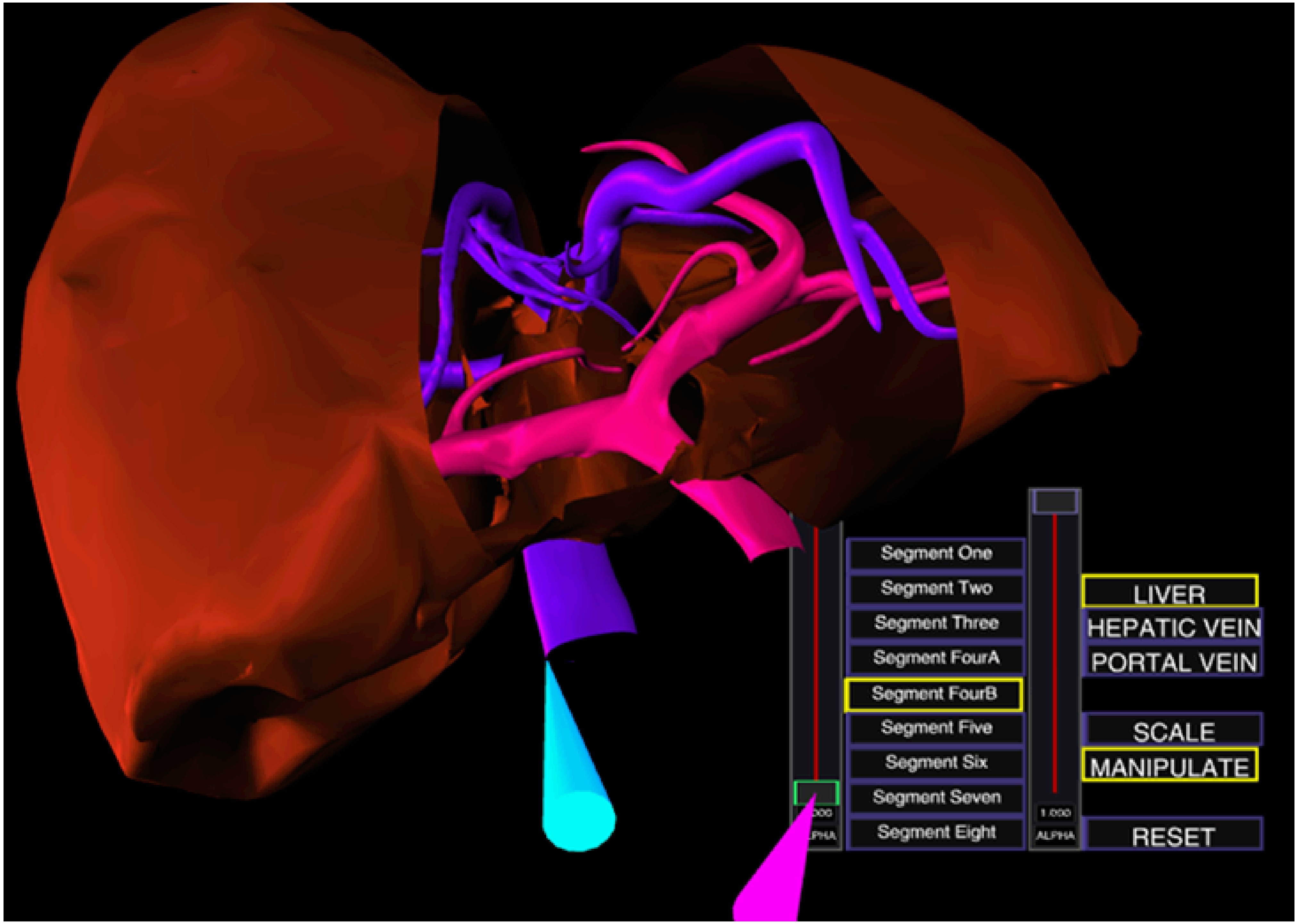
E-mail: jcs@uchicago.edu

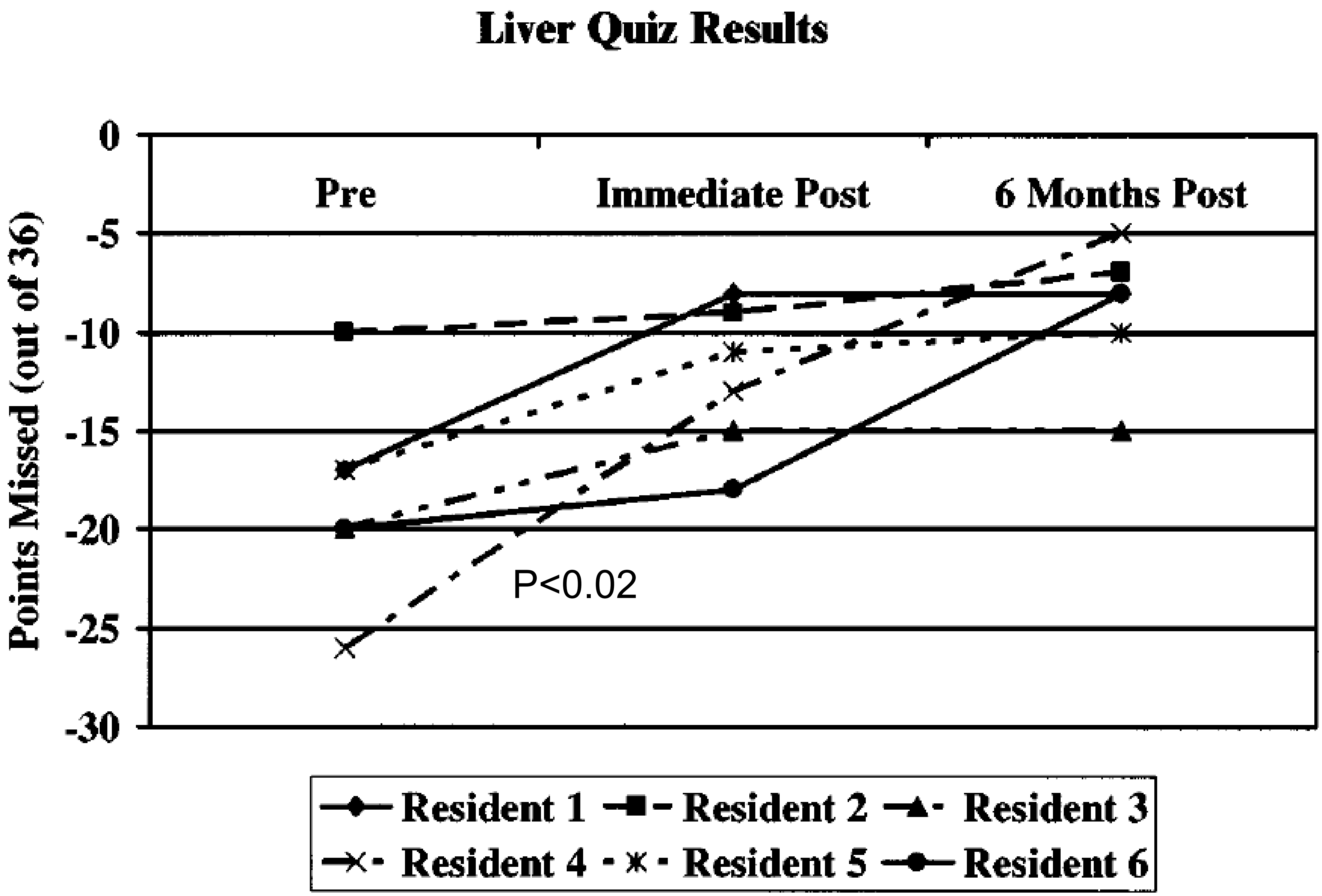
Computation Institute

Three-Dimensional Anatomy

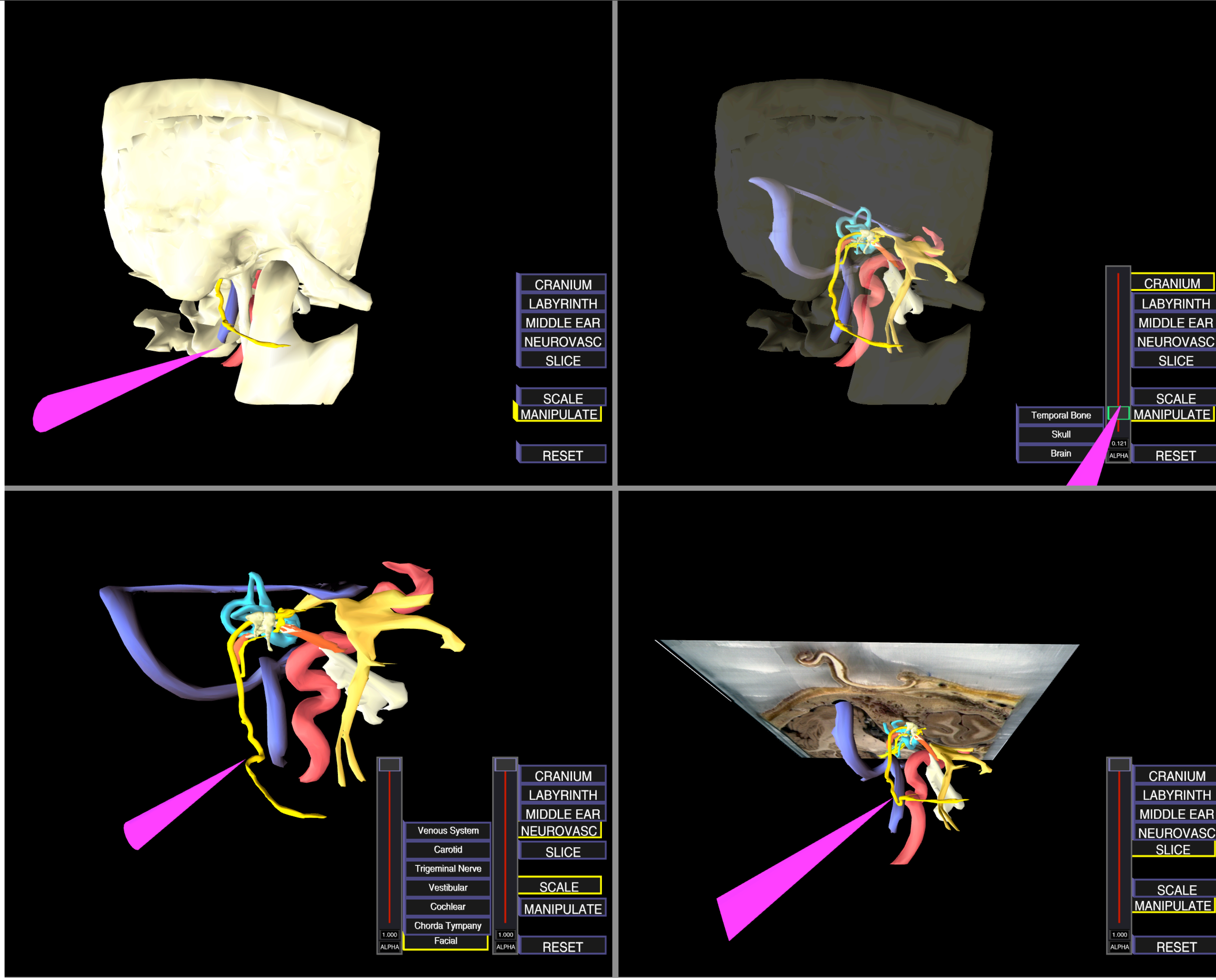
- Highly complex
- Critical to understanding common problems
- Surgeon's conceptual visualization difficult to achieve with lectures, 2D illustrations or images
- Cadaver dissection also difficult
- Few local experts in any region
- Consider virtual reality, teleconferencing and telepresence as solutions

Immersive Hepatic Surgery Educational Environment (IHSEE)



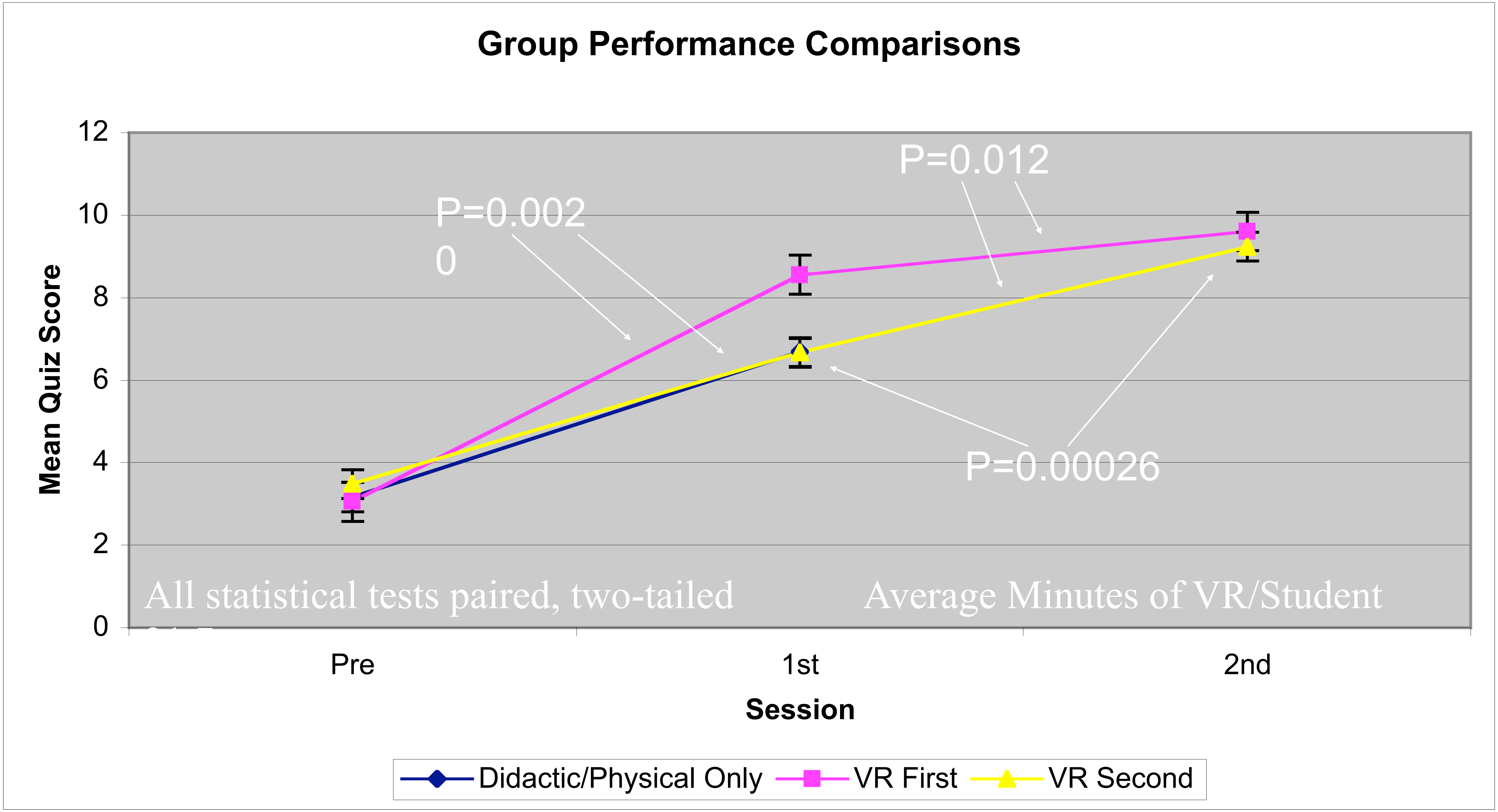


Silverstein JC, Dech F, Edison M, Jurek P, Helton WS, Espat NJ. Virtual Reality: Immersive Hepatic Surgery Educational Environment (IHSEE). Surgery. 2002 Aug;132(2):274-7.



CRANIUM
LABYRINTH
MIDDLE EAR
NEUROVASC
SLICE
SCALE
MANIPULATE
RESET
Temporal Bone
Skull
Brain
0.121
ALPHA
Venous System
Carotid
Trigeminal Nerve
Vestibular
Cochlear
Chorda Tympany
Facial
1.000

Results - Exam Data (Diffs)



Silverstein JC, Ehrenfeld JM, Croft D, Dech F, Small S, Cook S. Tele-Immersion: Preferred Infrastructure for Anatomy Instruction. Journal of Computing in Higher Education. Fall 2005; 18(1):80-93.

STUDENT CONSULT: Gray's Anatomy for Students

http://www.studentconsult.com/content/default.cfm?ISBN=0443066124 snomed cap

ELSEVIER STUDENT CONSULT

Jonathan Silverstein
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Drake et al: Gray's Anatomy for Students

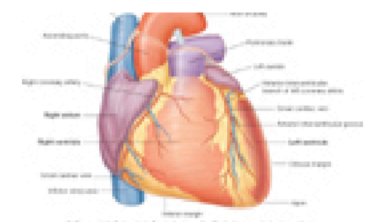

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Figure 3.58 Anterior surface of the heart.

page 158
page 159

Surfaces of the heart

The **anterior surface** faces anteriorly and consists mostly of the right ventricle with some of the right atrium on the right and some of the left ventricle on the left (Fig. 3.58).

The heart in the anatomic position rests on the **diaphragmatic surface**, which consists of the left ventricle and a small portion of the right ventricle separated by the posterior interventricular groove (Fig. 3.59). This surface faces inferiorly, rests on the diaphragm, is separated from the base of the heart by the coronary sinus, and extends from the base to the apex of the heart.

The **left pulmonary surface** faces the left lung, is broad and convex, and consists of the left ventricle and a portion of the left atrium (Fig. 3.59).

The **right pulmonary surface** faces the right lung, is broad and convex, and consists of the right atrium (Fig. 3.59).

Display a menu for "http://www.studentconsult.com/default.cfm"

Figure 3.58 Anterior surface of the heart.

Close

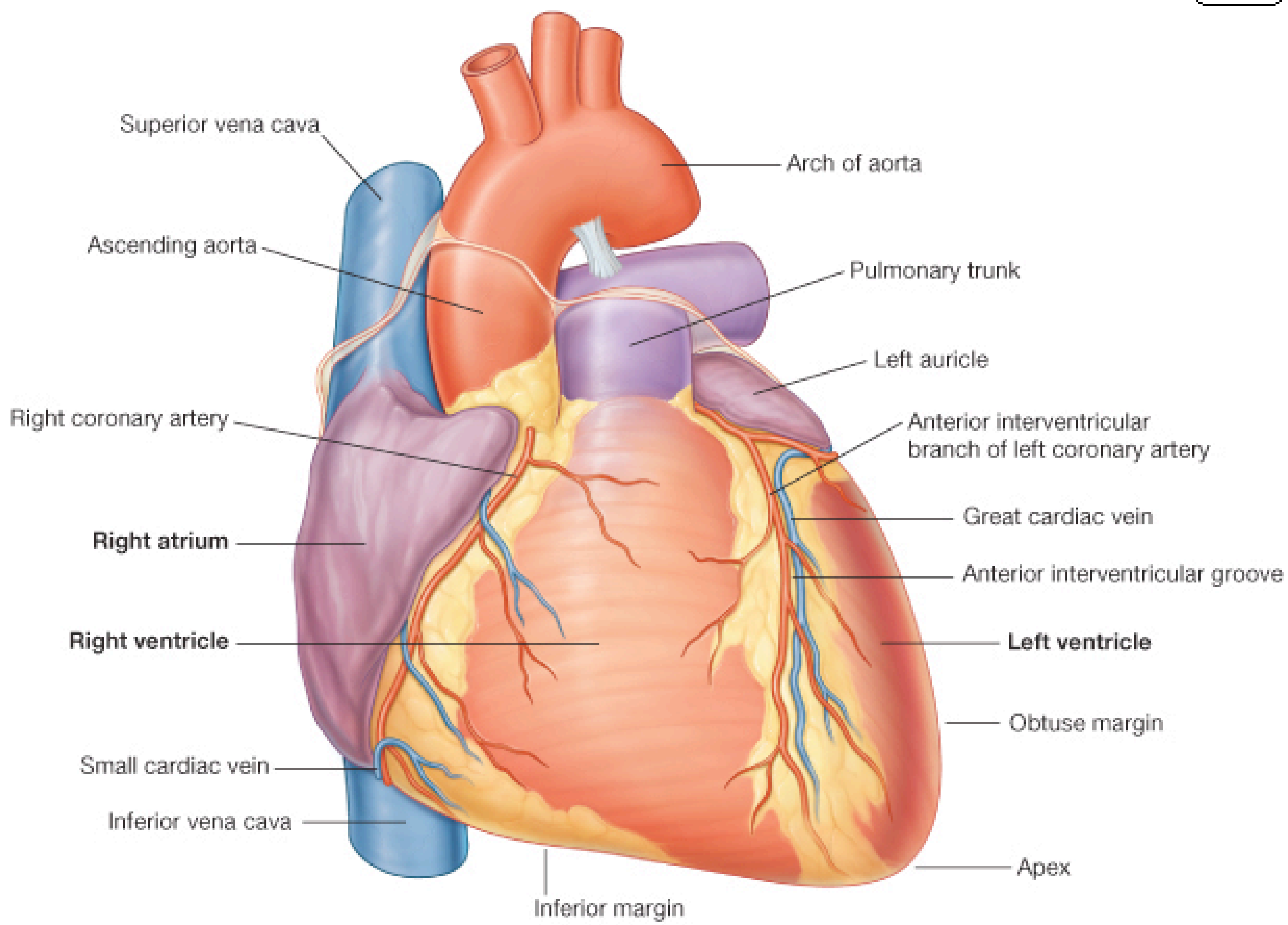

Figure 3.58 Anterior surface of the heart.

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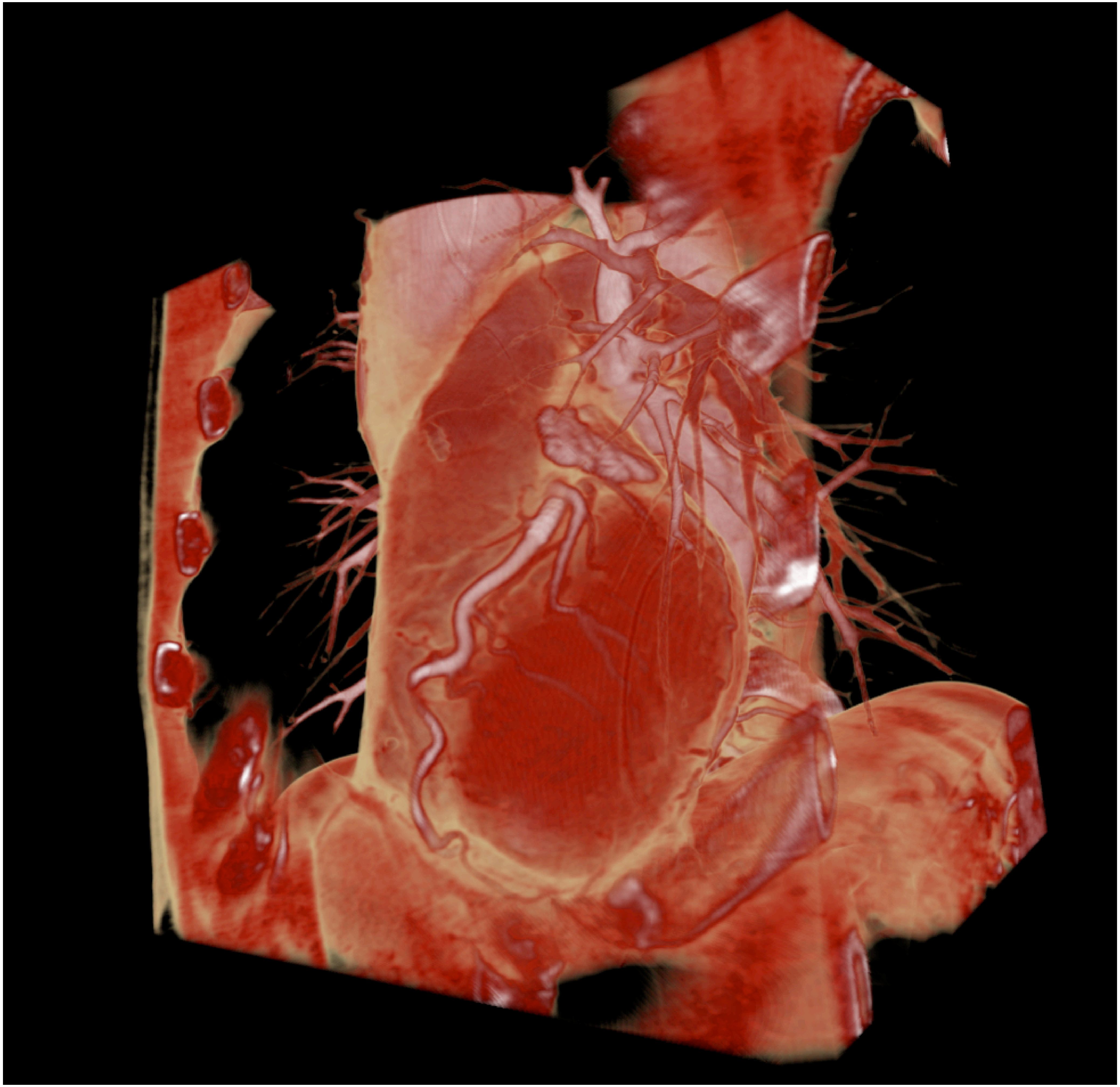
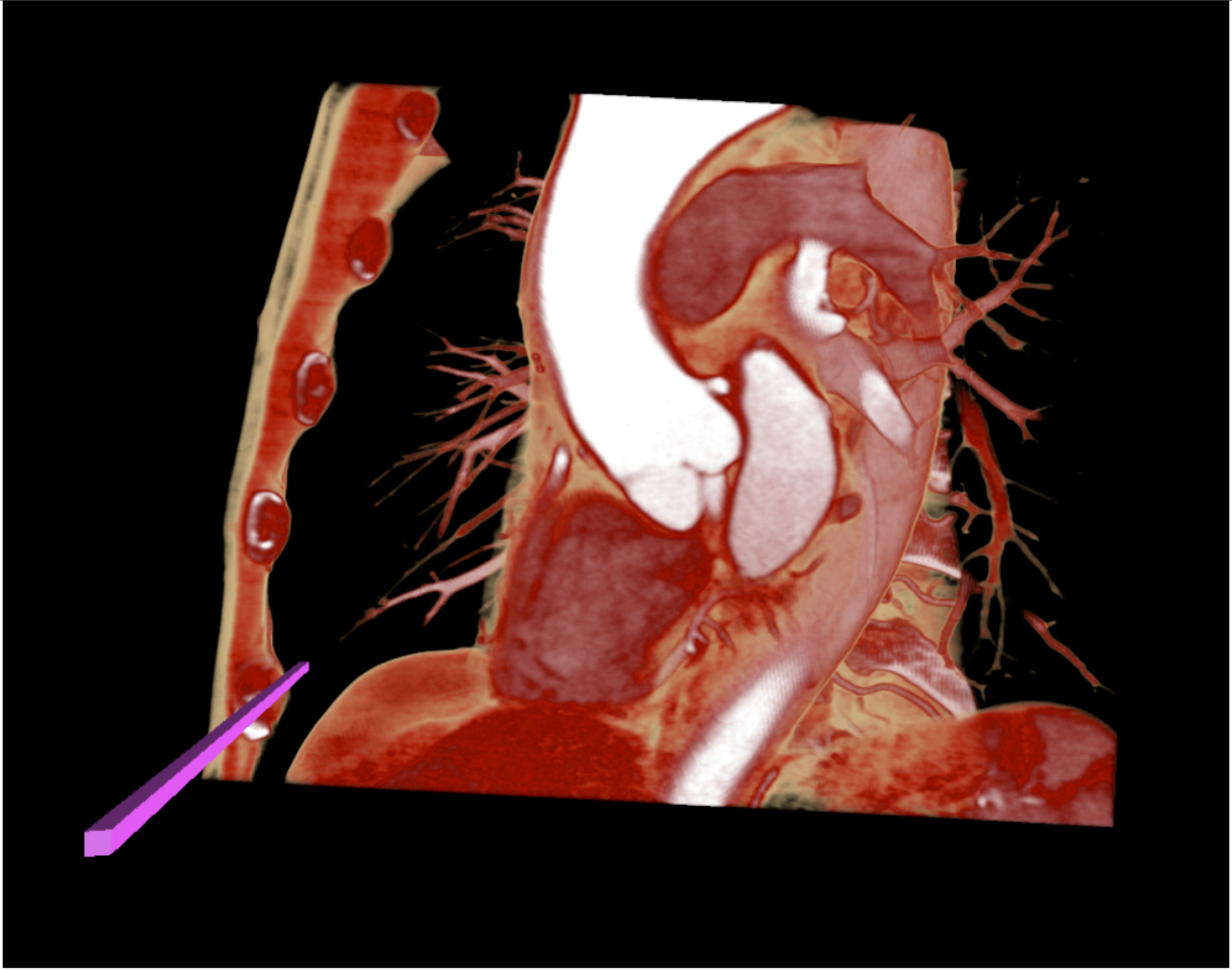




Mean (s.d.) value element assessments (N=7)

Value Element Assessed	Enjoyment	Value in learning	Efficiency in learning	Contribution to mental model or framework of learning	Contribution to ultimate understanding	Total Value (calc)
Paper Textbook	3.9 (0.3)	4.4 (0.5)	3.7 (0.7)	4.1 (0.3)	4.6 (0.5)	4.1 (0.3)
Paper Atlas	3.9 (0.6)	4.6 (0.7)	3.7 (1.2)	4.4 (0.5)	4.8 (0.4)	4.3 (0.4)
Virtual Reality	4.9 (0.3)	4.3 (0.5)	3.6 (0.9)	4.4 (0.7)	4.4 (0.5)	4.3 (0.4)

1 = poor, 2=fair, 3=good, 4=very good, 5=excellent

Ratings of Undergraduate Course by Students. Includes all University of Chicago Biological Sciences Collegiate Division courses (N=5)

Factor Assessed	Immersive Virtual Anatomy Course	Average Rating for all Courses Spring 2005-06
Organization of Course	4.5	4.2
Value of Material	4.9	4.2
Demands and Expectations	4.5	4.2
Overall Rating	4.4	4.1

5=Strongly Agree. Note that students also reported Mean (s.d.) of 6.6 (1.82) hours preparation per week.

Real-Time Automated Hepatic Explant Volumetrics on a Stereoscopic, Three-Dimensional Parallelized Visualization Cluster

+^*Jonathan C. Silverstein, +Nigel M. Parsad, +J. Michael Millis, +Giuliano Testa, ^Michael W. Vannier, +Fred Dech, *Eric Olson, *Michael E. Papka, *Rick Stevens

University of Chicago

+Surgery, ^Radiology, *Computation Institute of UC/ANL

Fourteenth Annual Charles B. Huggins Research Conference

Department of Surgery, University of Chicago Medical Center

May 5th, 2007

The Problem: Liver Transplant Rehearsal

- Healthy donor liver graft must be transplanted to recipient.
- Remove too much liver volume, donor's life is at risk. Remove too little liver volume, recipient's life is at risk.
- High resolution CT scanners provide liver transplant surgeons and radiologists hundreds (~500) of 2D axial CT slices of healthy donor's liver to refine explant dimensions.

Status Quo Solution

- Radiology techs "paint" explant cross section areas per slice axial slice and then sum the slices to derive explant volume based upon pre-surgical plan.
- Time constraints limit radiology techs ability paint *each* 2D axial abdominal CT slice. Rather, they paint a few cross-sectional areas and then rely on *interpolation* software to derive the rest. This introduces error in the volume computation.
- Transplant surgeons may request multiple explant resection plans per donor patient compounding the time/ error issue.

Sources of Error

- CT examination technique
- Partial volume effects
- Conversion factor between blood-free graft weight and blood-filled graft volume
- Surgeons most likely do not incise through the liver in a plane that directly correlates with that as determined from transverse CT images.

Lemke et al. Radiology 2006; 240:736–742

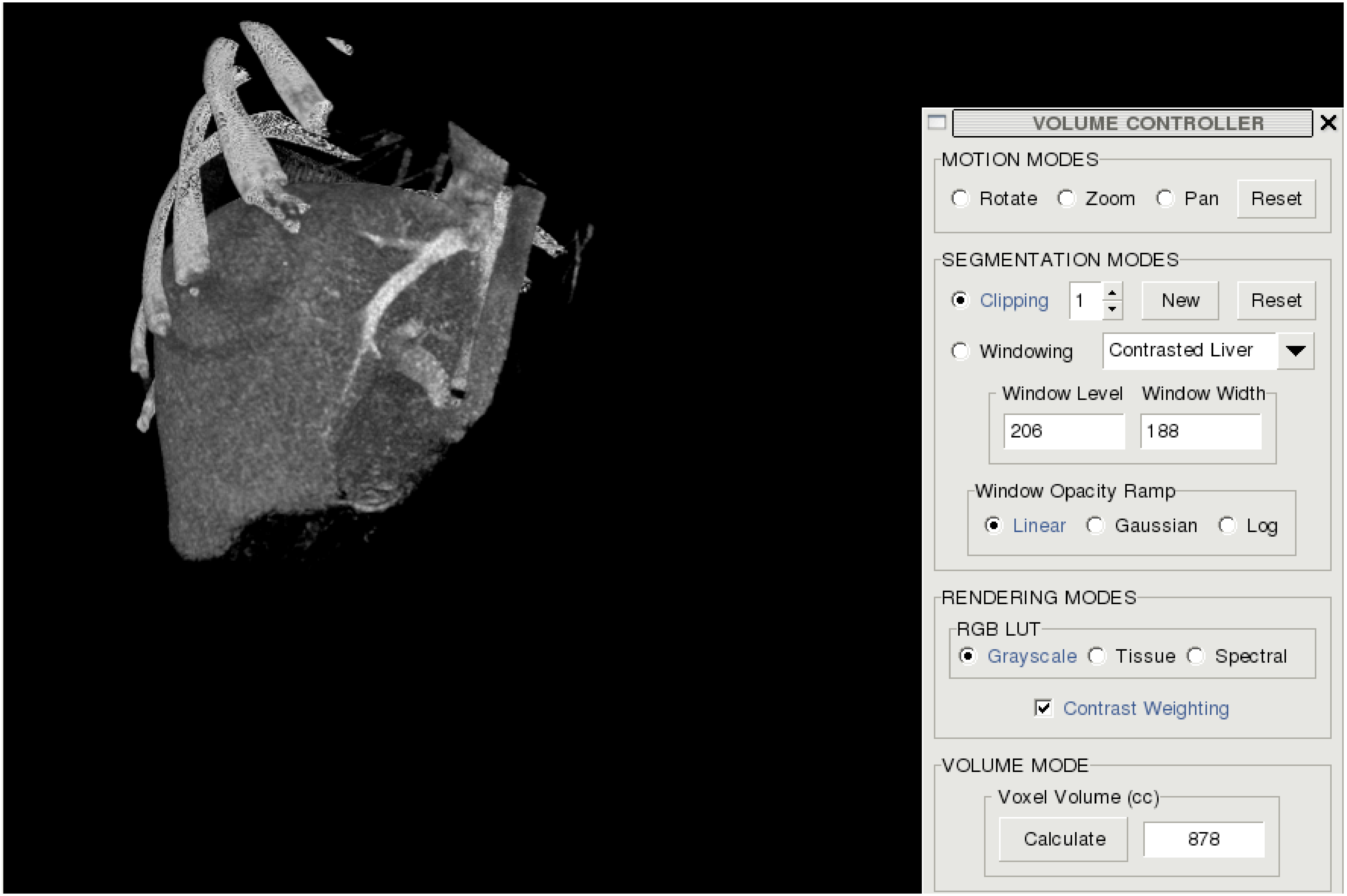
Methods: Cutting Edge Solution

- UC/ANL 3D stereo volume rendering engine enables surgeons to visualize and interactively manipulate aspects of the hepatic anatomy not easily resolvable from 2D CT slices.

- Multiple cutting planes allow surgeons to virtually resect the donor's liver quickly and iteratively (reduces error of direct correlation with actual surgery).

- Utilizing the dynamic density range of the virtual graft resection, precise explant volumes are calculated in *seconds* eliminating the pixel painting/interpolation step (reduces error of partial volume effects).

- Volume computation becomes a *real-time, interactive tool* available to the surgical team to consider multiple options during the virtual rehearsal.



VOLUME CONTROLLER
MOTION MODES
Rotate
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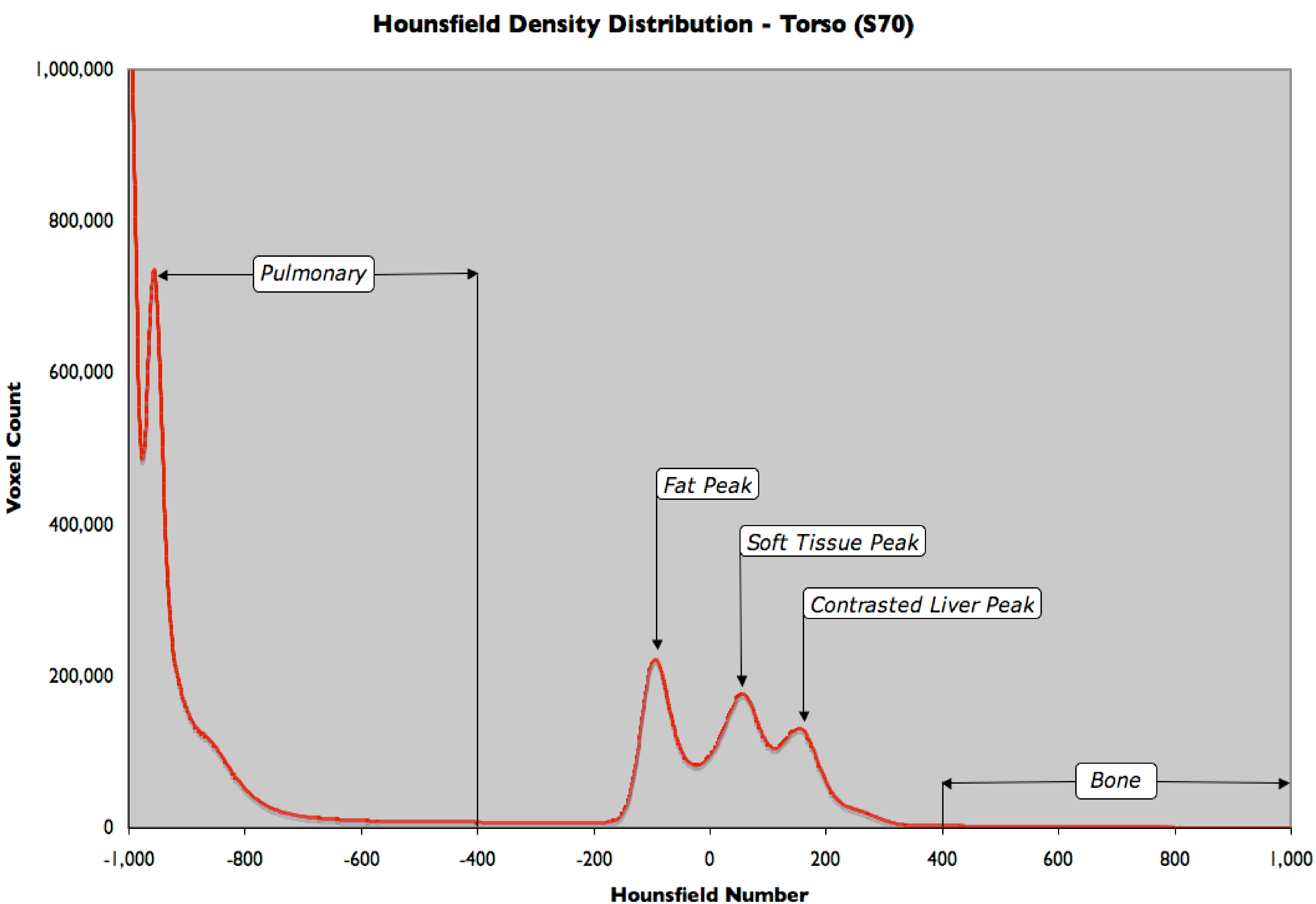
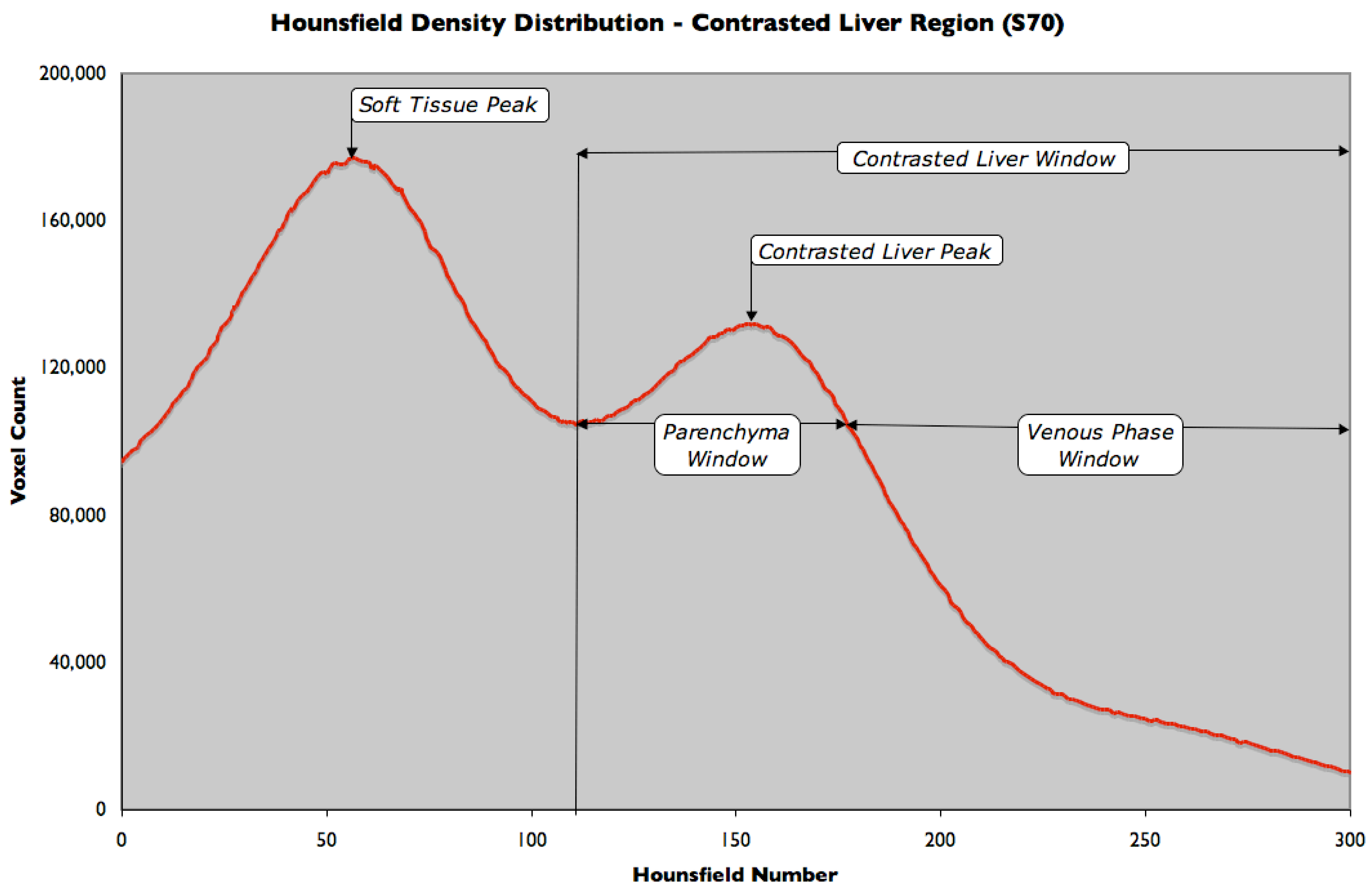
SEGMENTATION MODES
Clipping
1
New
Reset
Windowing
Contrasted Liver
Window Level
Window Width
206
188
Window Opacity Ramp
Linear
Gaussian
Log
RENDERING MODES
RGB LUT
Grayscale
Tissue
Spectral
Contrast Weighting
VOLUME MODE
Voxel Volume (cc)
Calculate
878

Automated Segmentation of Hepatic Structures

- *Consistent* virtual graft visualization, resection and volume computation requires accurate segmentation of venous phase contrasted hepatic structures from the rest of the abdomen.
- Our software determines *a priori* the 'contrasted liver' HU density window specifically for each patient CT dataset via HU distribution extrema analysis using Savitsky-Golay statistical filtering.
- A 'contrasted liver' density window setting is a preset choice available to the surgical planning team eliminating the need to manually find the desired hepatic anatomy.



Hounsfield Density Distribution - Torso (S70)
Voxel Count
1,000,000
800,000
600,000
400,000
200,000
0
Pulmonary
Fat Peak
Soft Tissue Peak
Contrasted Liver Peak
Bone
-1,000
-800
-600
-400
-200
0
200
400
600
800
1,000
Hounsfield Number

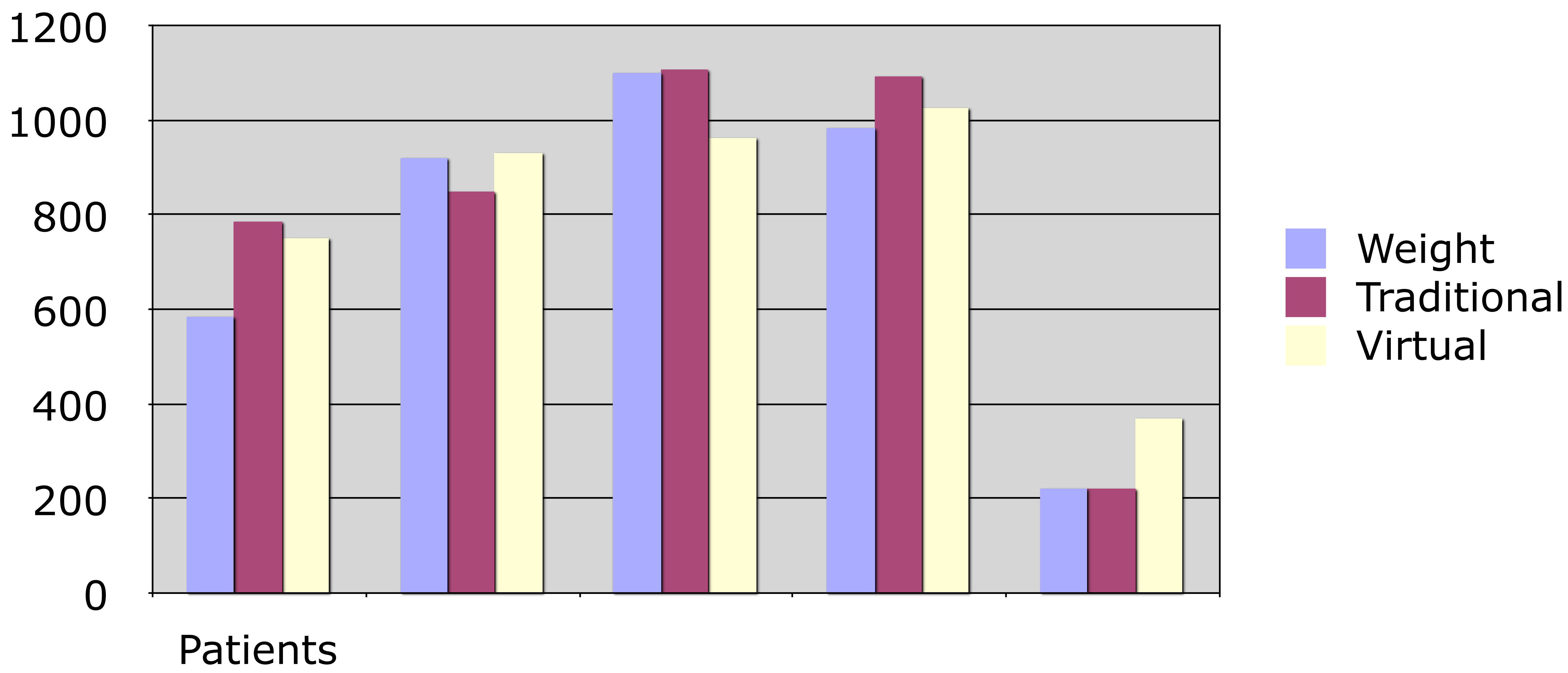


Hounsfield Density Distribution - Contrasted Liver Region (S70)
200,000
160,000
120,000
80,000
40,000
0
Voxel Count
0
50
100
150
200
250
300
Hounsfield Number
Soft Tissue Peak
Contrasted Liver Window
Contrasted Liver Peak
Parenchyma Window
Venous Phase Window

Automated Volume Computation Algorithm

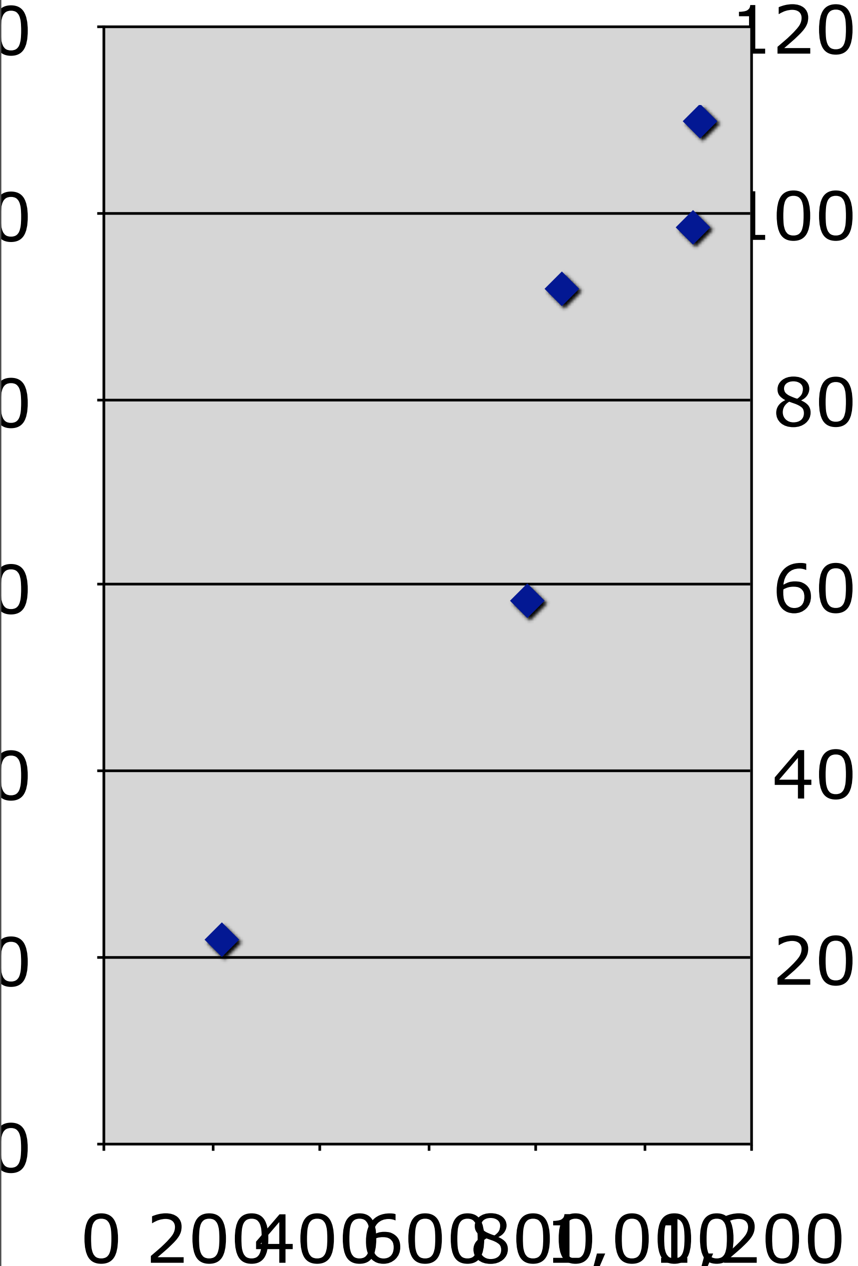
- Surgical team selects 'Contrasted Liver' window preset from the visualization environment's GUI.
- Surgeons manipulate the 3D stereoscopically reconstructed hepatic anatomy and use multiple cutting planes to resect a virtual explant ROI.
- Team member presses GUI's "Calculate" button.
- Volume computation algorithm iterates through the dataset's voxels and sums those whose coordinates lay within the ROI and whose HU values reside within the contrasted liver range.

Results: Raw Data



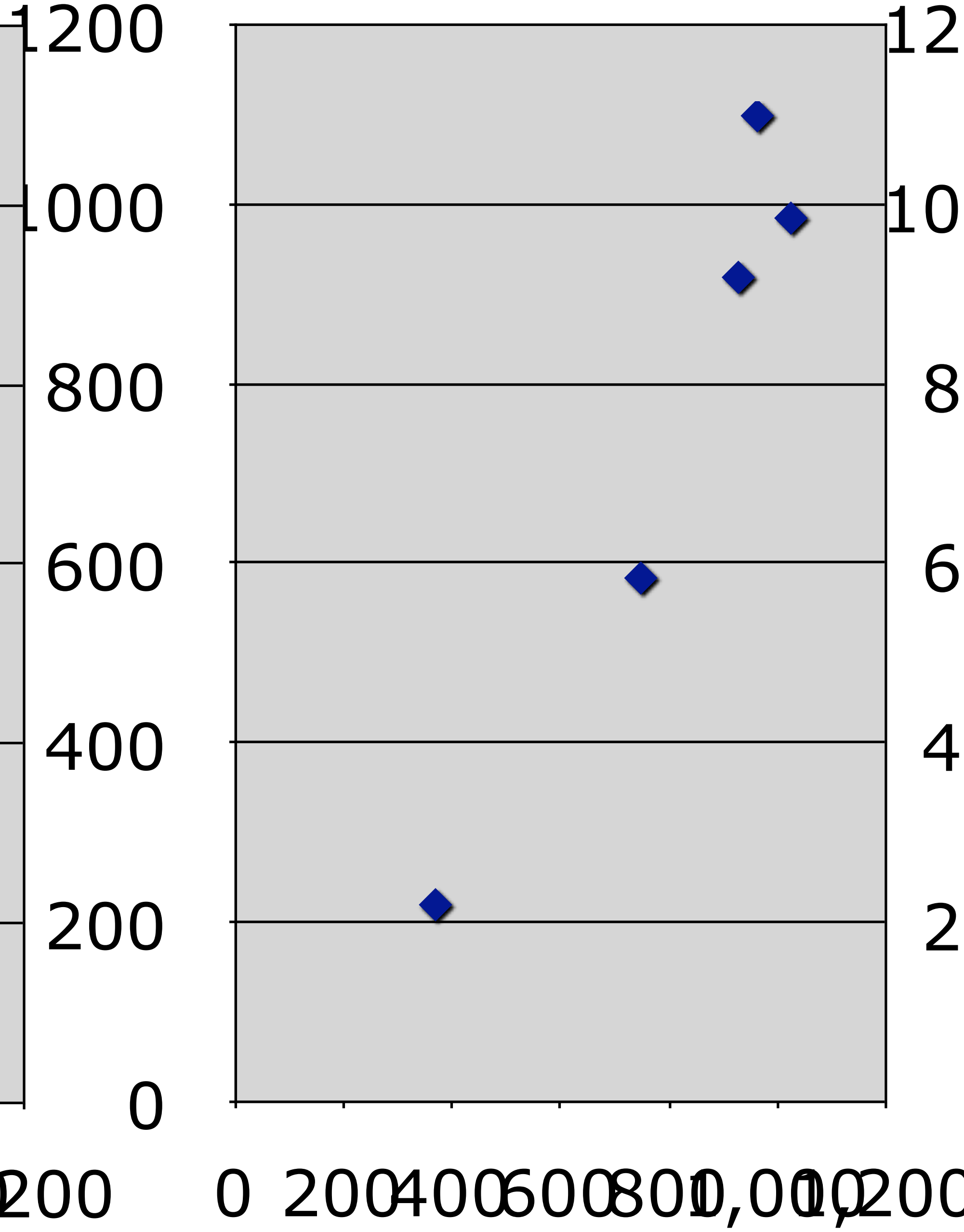
Results: Correlations

Actual to Traditional



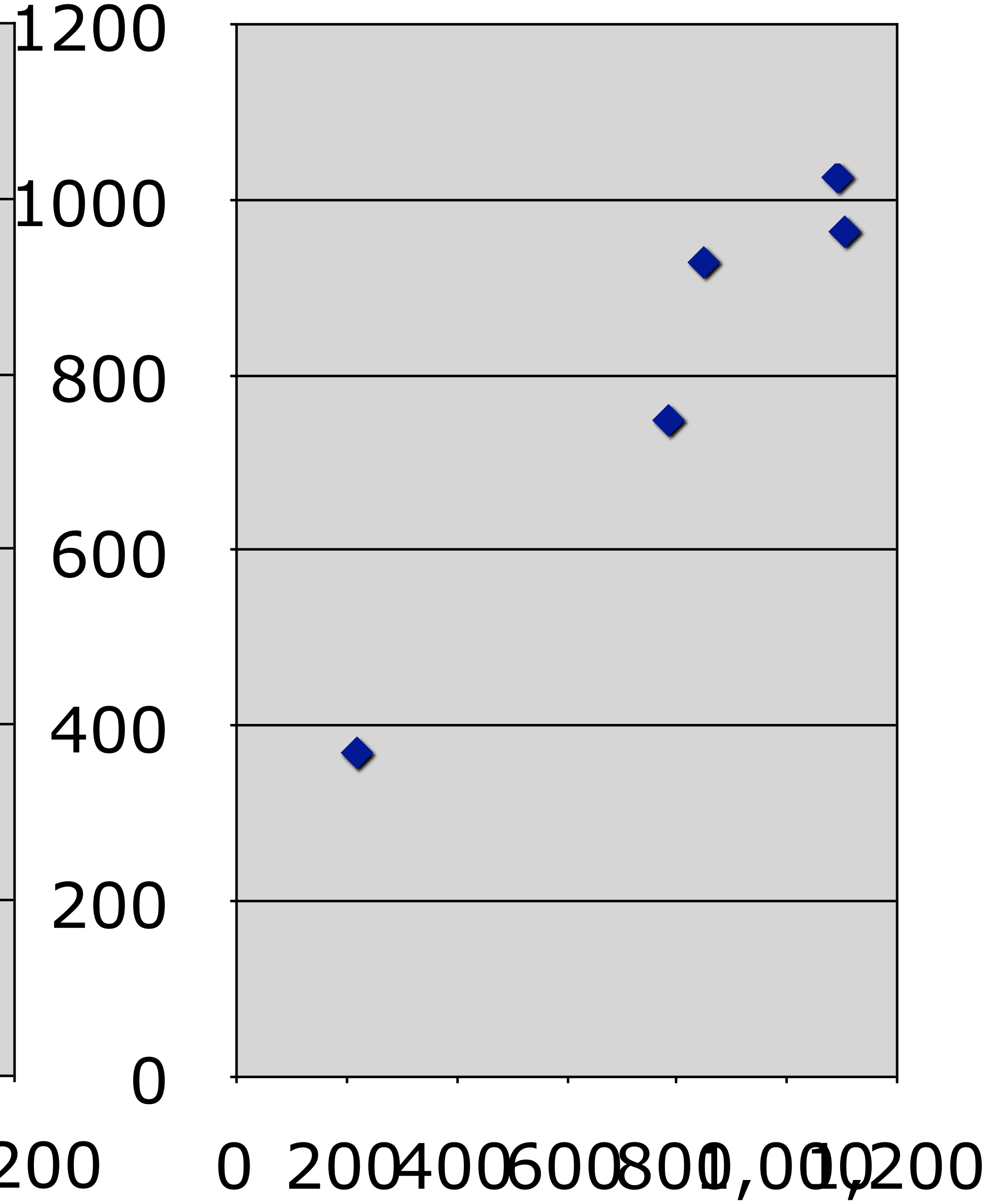
y = 0.9523x - 10.864
$R2 = 0.9147$

Actual to Virtual



y = 1.3061x - 293.68
$R2 = 0.9364$

Traditional to Virtual



y = 0.7193x + 224.5
$R2 = 0.9508$

Conclusions

- Virtual Reality Surgical Rehearsal is feasible and desirable to the transplant team
- Sources of error can be reduced with virtual reality methods
- Automated volume calculation is as accurate or more accurate than traditional methods
- More surgical options can be considered by the surgeons in real time

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Globus MEDICUS
-
Federation of DICOM Medical Imaging Devices into Healthcare Grids

Jonathan C. Silverstein, Stephan G. Erberich,
Ann Chervenak, Robert Schuler, Marvin D. Nelson,
Carl Kesselman

Globus MEDICUS

- Medical Imaging and Computing for Unified Information Sharing (MEDICUS)
- Addresses Medical Imaging
  - DICOM image sharing within Grids*
  - DICOM image archiving (Grid PACS)**
  - DICOM image processing

*PACS and Imaging Informatics, SPIE Medical Imaging, 6145-32, 2006

**Int Journal of Computer Assistant Radiology and Surgery, 2006, 1:87-105; p100-104, Springer, Heidelberg

Medical Imaging Grid: Nuts and Bolts

- DICOM images
  - Send (publish)
  - Query/Retrieve (discover)
- Grid Archive
  - Fault tolerant
  - Bandwidth
- Security
  - Authentication
  - Authorization
  - Cryptography
- Access
  - Web portal
- Applications
  - Computing
  - Data Mining

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Medical Imaging Grid: Nuts and Bolts

Globus Toolkit Release 4

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Globus Toolkit Release 4

DICOM Grid Interface Service (DGIS)
+
Meta Catalog Service (OGSA-DAI)

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X.509 Certificates
Shibboleth / GridShib
MyProxy Delegation

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Globus Toolkit Release 4

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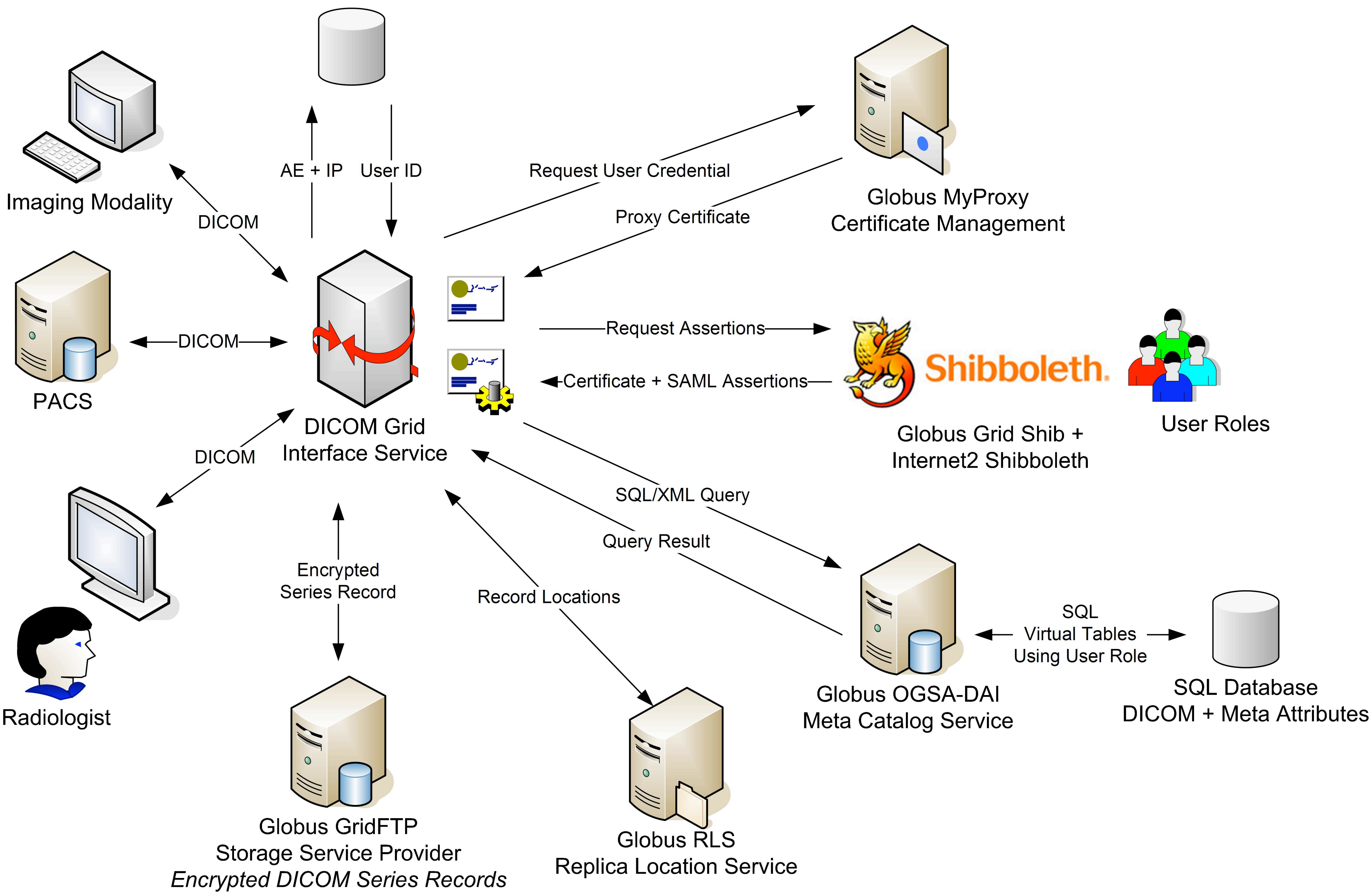
MEDICUS v2 - Medical Image Workflow



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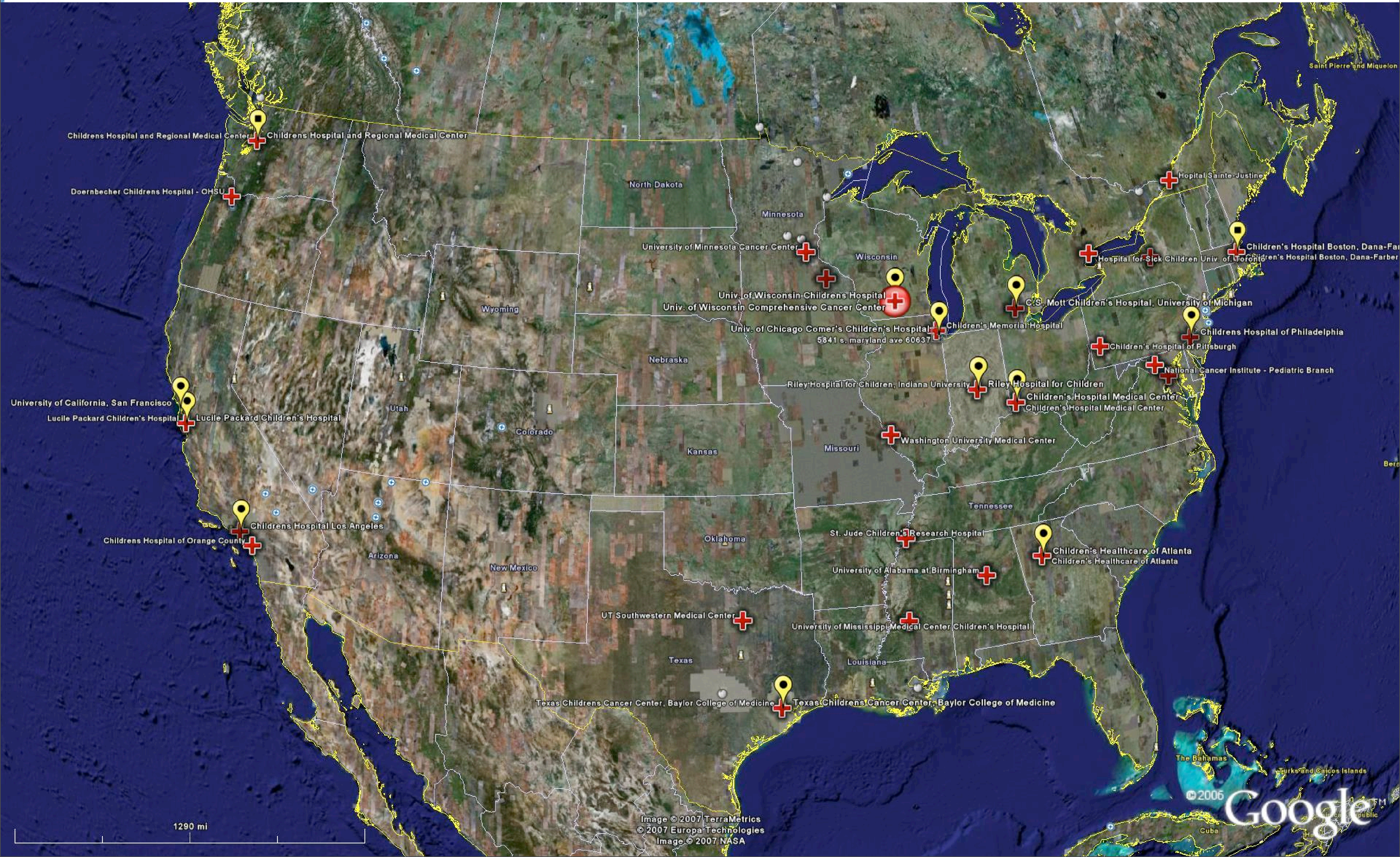
MEDICUS use cases: Childrens Oncology Group and Neuroblastoma Cancer Foundation Grids



Summary

- MEDICUS vertically integrates standards based GT4 components – “No reinventing the wheel”
- Fast and efficient DICOM off-site storage
- Transparent image workflow for Physician
- Off-site storage alternative to expensive PACS
- Flexible and cost efficient deployment using open-source (~ $500 per TG)
- FT and DR by Grid provided replication

Conclusion

- MEDICUS present one piece to the HealthGrid puzzle
- Modular SOA design ideal for collaborative extension, e.g. image processing web services using DICOM image resource on the Grid
- Open-source community build:
  You are invited to contribute your field of expertise
  dev.globus.org/wiki/Incubator/MEDICUS

Considerations of Applications, Middleware and Network Infrastructure to Support Medicine

- Adherence to Open Standards - Many Entities Participating
- On-Demand Bandwidth with Massive Capacity - Highly Variable, but Immediate, Real-Time Needs
- High Reliability / Redundancy - Zero Tolerence for Error
- Secure Channels (auditable?) - Privacy is Paramount
- Auto and Manual Bandwidth Throttles - Wireless Design
- Importance of "Small" Science / Medicine - Systems are Partial
- Systems Must Handle Change Without Reconfiguration - Constantly New Data, Users, Technologies and Standards
- Versioning / Provenance - Incentives for Data Sharing

HEALTHGRID 2008

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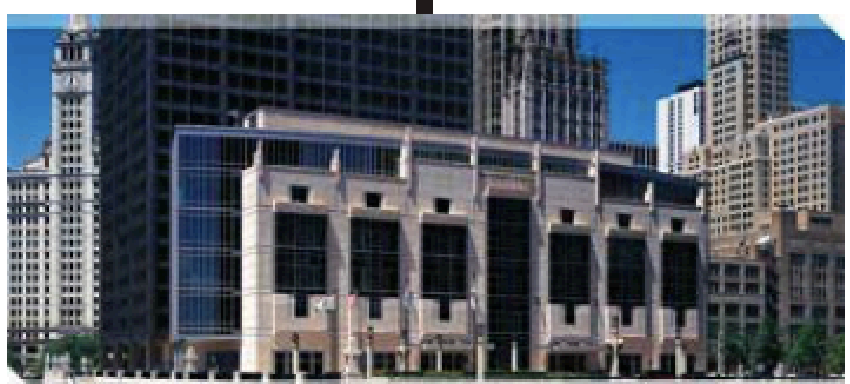

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Chicago, Illinois, USA

June 2-4, 2008

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