A Tele-Immersive System for Surgical Consultation and Implant Modeling

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Collaborators

- Virtual Reality in Medicine Lab
  - Zhuming Ai
  - Ray Evenhouse
  - Mary Rasmussen
- Electronic Visualization Lab
  - Jason Leigh
  - Dan Sandin
  - Greg Dawe
  - Tom DeFanti
- Department of Neurosurgery
  - Fady Charbel

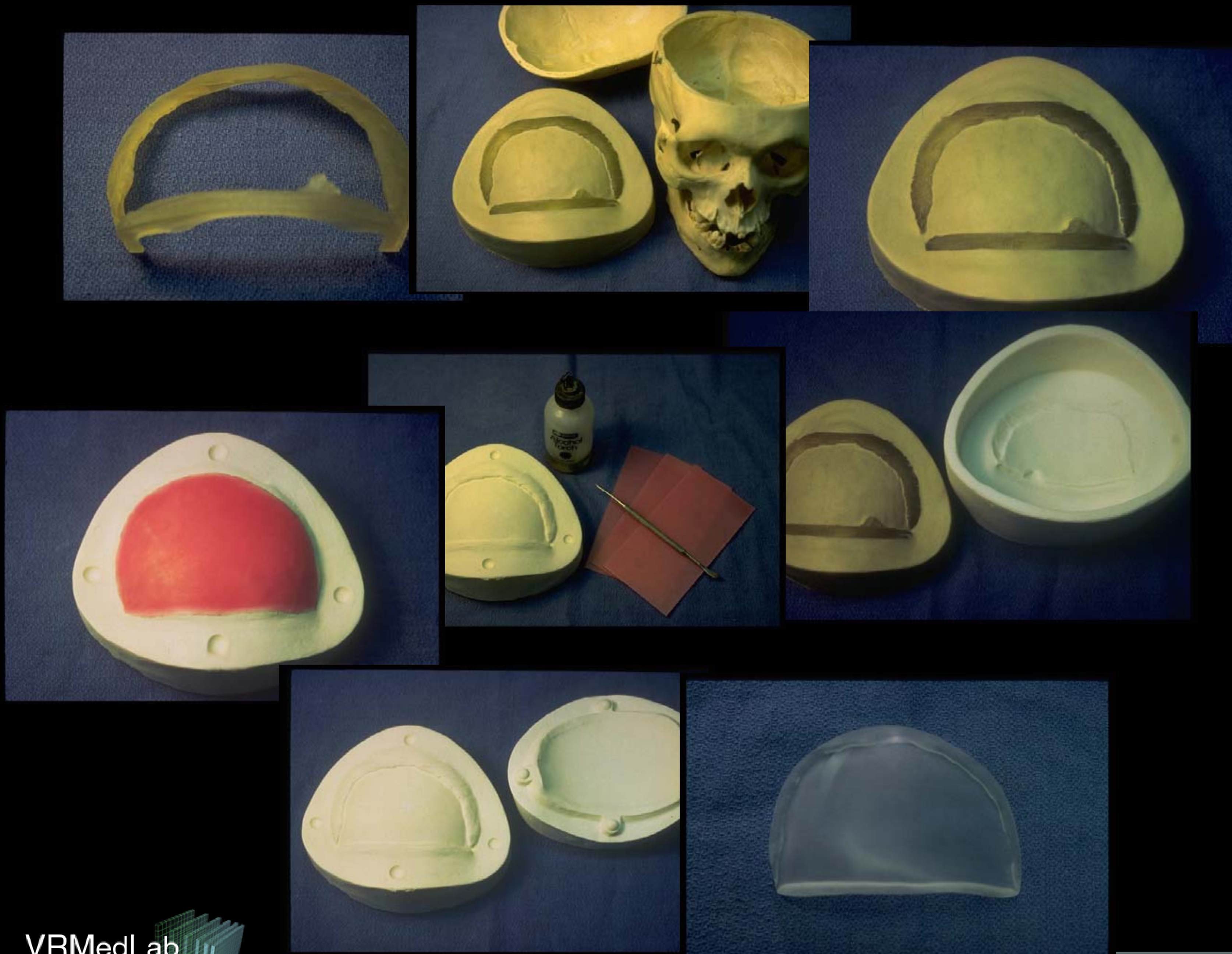
Introduction

- The number of injuries resulting in large cranial defects is increasing
- It is difficult to assemble the expertise necessary to repair large cranial defects
- Traditional methods
  - Heavily dependent on subjective skills and procedures
  - Poor fit
  - Revisions are needed during the surgical placement of the implant
  - Long operating room times

Previous Work:
Using CT data in a CAD environment

Steps in 1996 implant production method

- Data acquisition (CT scan)
- Digital modeling
- Stereolithography of “Defect”
- Sculpting of implant form
- Mold-making
- Implant fabrication



Benefits of 1996 Method

- Operating room time reduced by 2/3
- Reduction of patient stay in hospital
  1-2 days instead of 5-7
- Protection of delicate brain tissue
- Restoration of normal appearance
- Elimination of pain at the defect site
- Improved cognitive function (in some cases)
- In none of the cases was it necessary to alter
  either the defect or implant for a precise fit

Negatives of 1996 Method

Too many slow/expensive steps in process

- Data Acquisition
- Digital modeling
- Stereolithography of “Defect”
- Sculpting of implant form
- Mold-making
- Implant fabrication
- Consultation between Surgeon, Patient and Modeler is often difficult
- Implants often take weeks to produce

Strategy

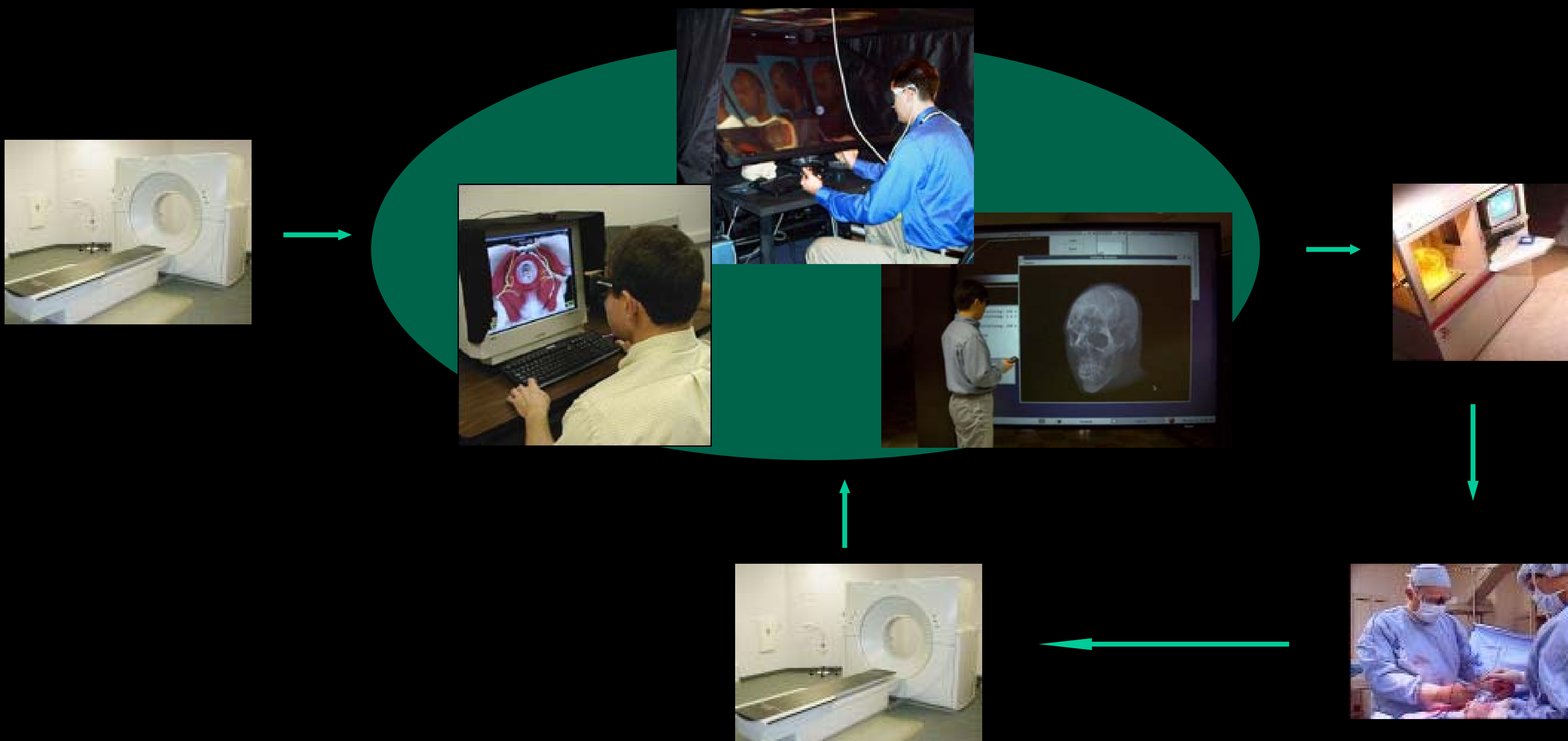
- Advanced networks
- Advanced visualization techniques
- Computer-controlled rapid prototyping systems

General Approach

Networked tele-immersive collaborative surgical system

- Surgical pre-planning, consultation
- Implant design
- Post operative evaluation and education

General Approach



Components

- Augmented reality implant modeling system
- Modeling software
- Implant design
- Surgical consultation over networks

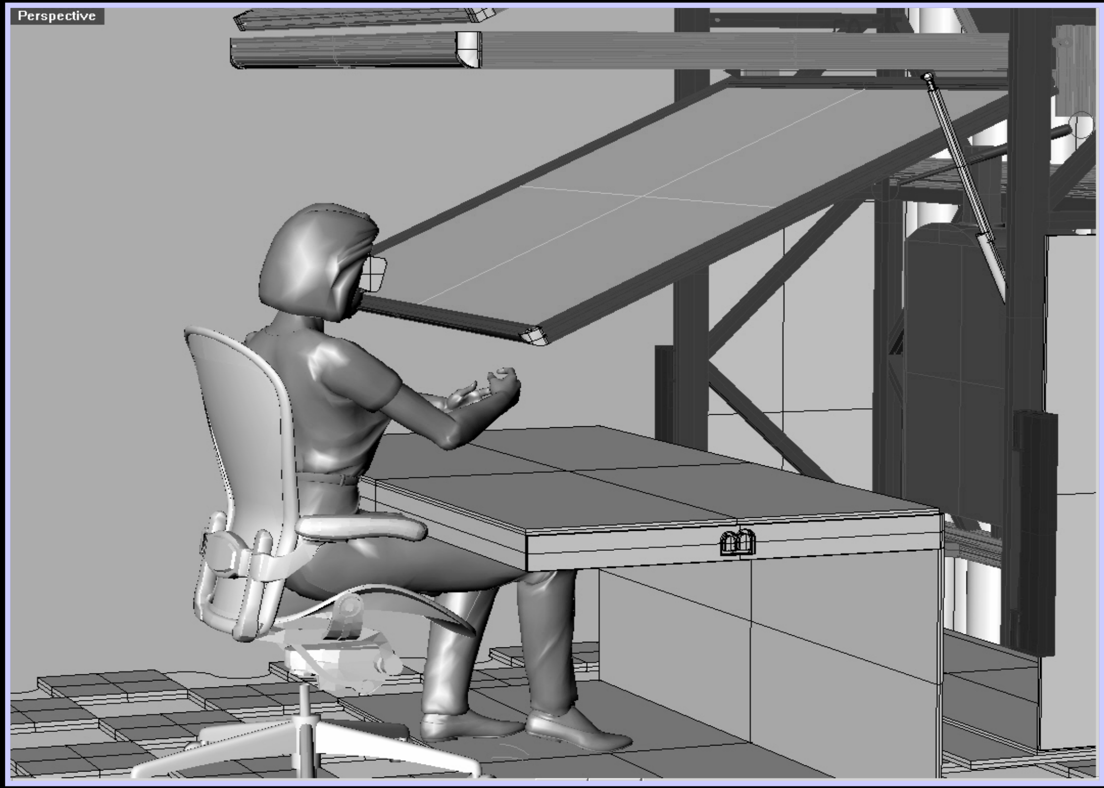
Implant Modeling System

- To simulateg the traditional sculpting workspace

- Stereo Vision
- Viewer centered perspective
- Sense of touch
- Collaboration

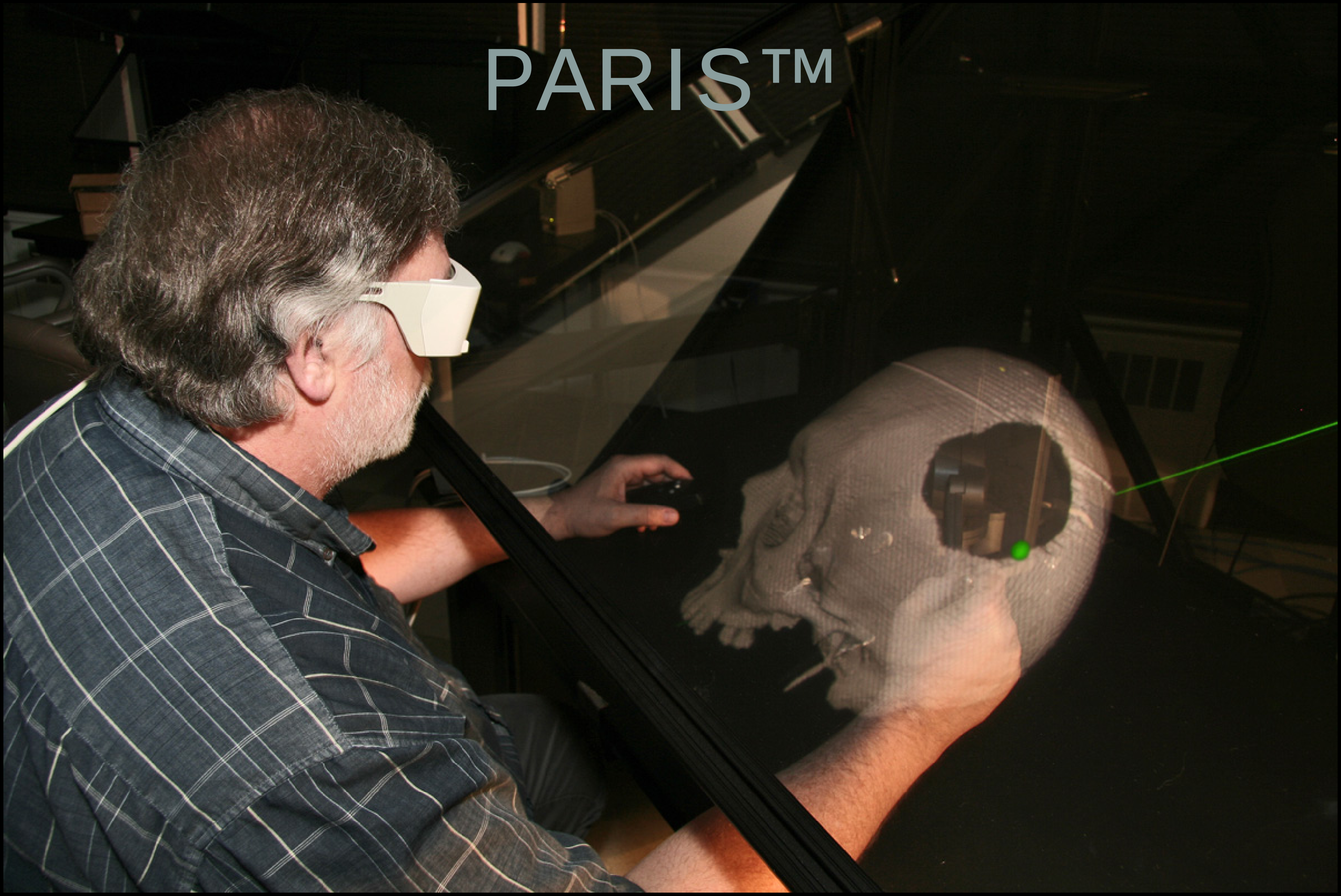
Personal Augmented Reality Immersive System
PARIS™

- Virtual reality
- Augmented reality
- Haptic reality



PARIS™

PARIS™



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Components

- Augmented reality implant modeling system
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Modeling Software

– Creation of precisely fitting cranial implant

- The specification and design of complex and arbitrary 3D shapes is very difficult
- Shapes are best generated by sculpting procedures in 3D
- 3D visual display
- Sense of touch

Immersive Implant Modeling With Haptics

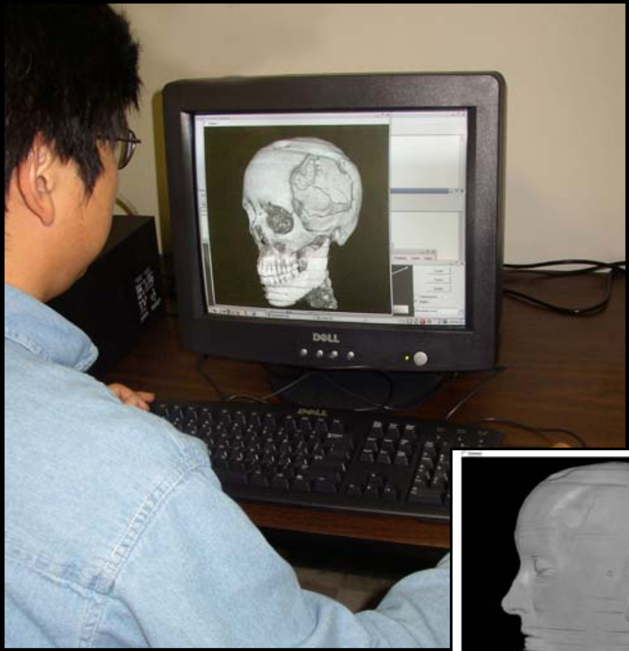
- Polygonal Models
- Volumetric models

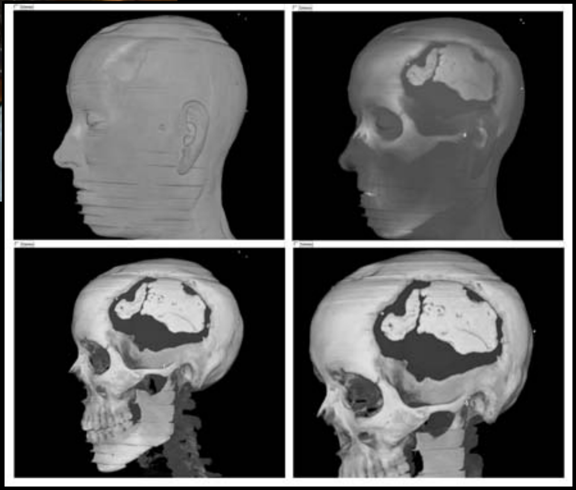
Immersive Implant Modeling on Volumetric Data With Haptics

- Direct volume rendering
- Proxy-based force feedback algorithm

Direct Volume Rendering

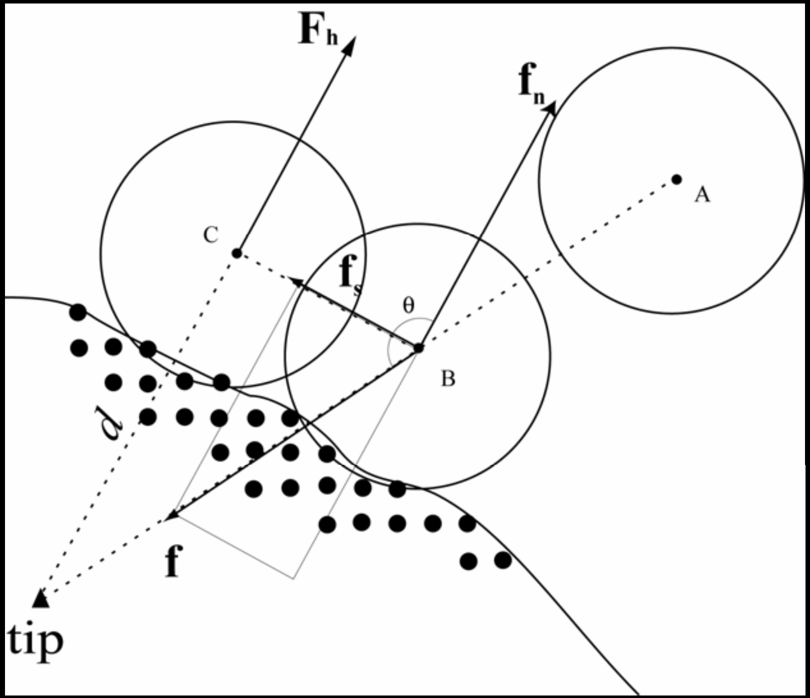
- Visual and haptic feedback latency
- Hardware assisted 3D texture map algorithm
- Level of detail
- Algorithm optimization





Haptic Rendering

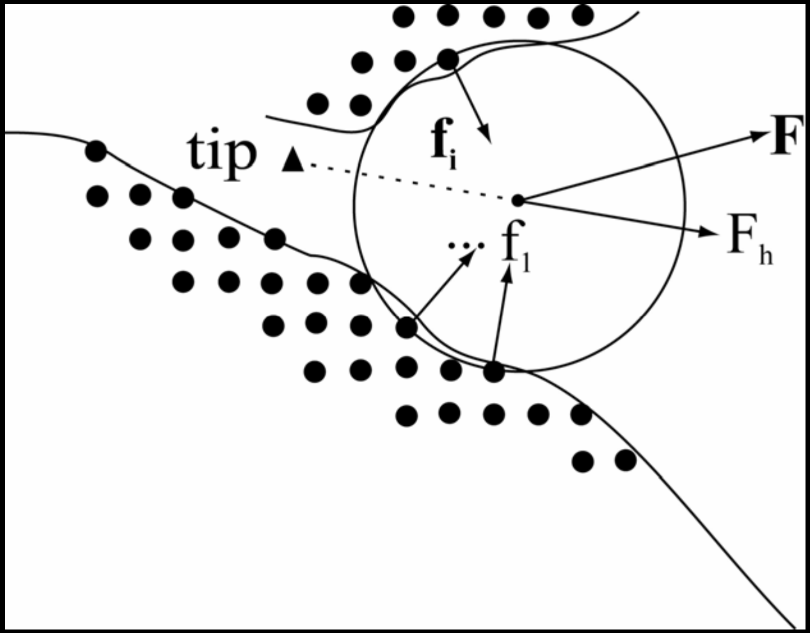
- Tool is not allowed to penetrate the bone
- $F_h = -kd$
- Movement of the Proxy
  - moves straight to the tip point before it reaches the object (A to B)
  - moves on the surface of the object perpendicular to the surface normal (B to C)



Haptic Rendering

- Spherical proxy
- Force Calculation

F=©f_i



Components

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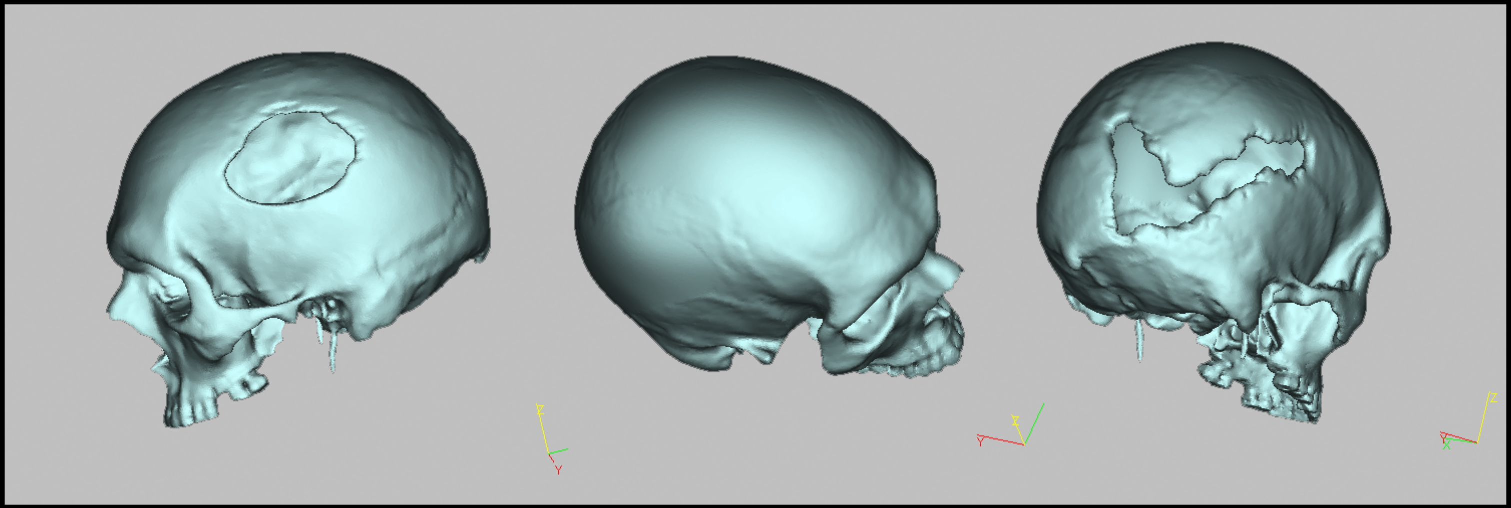
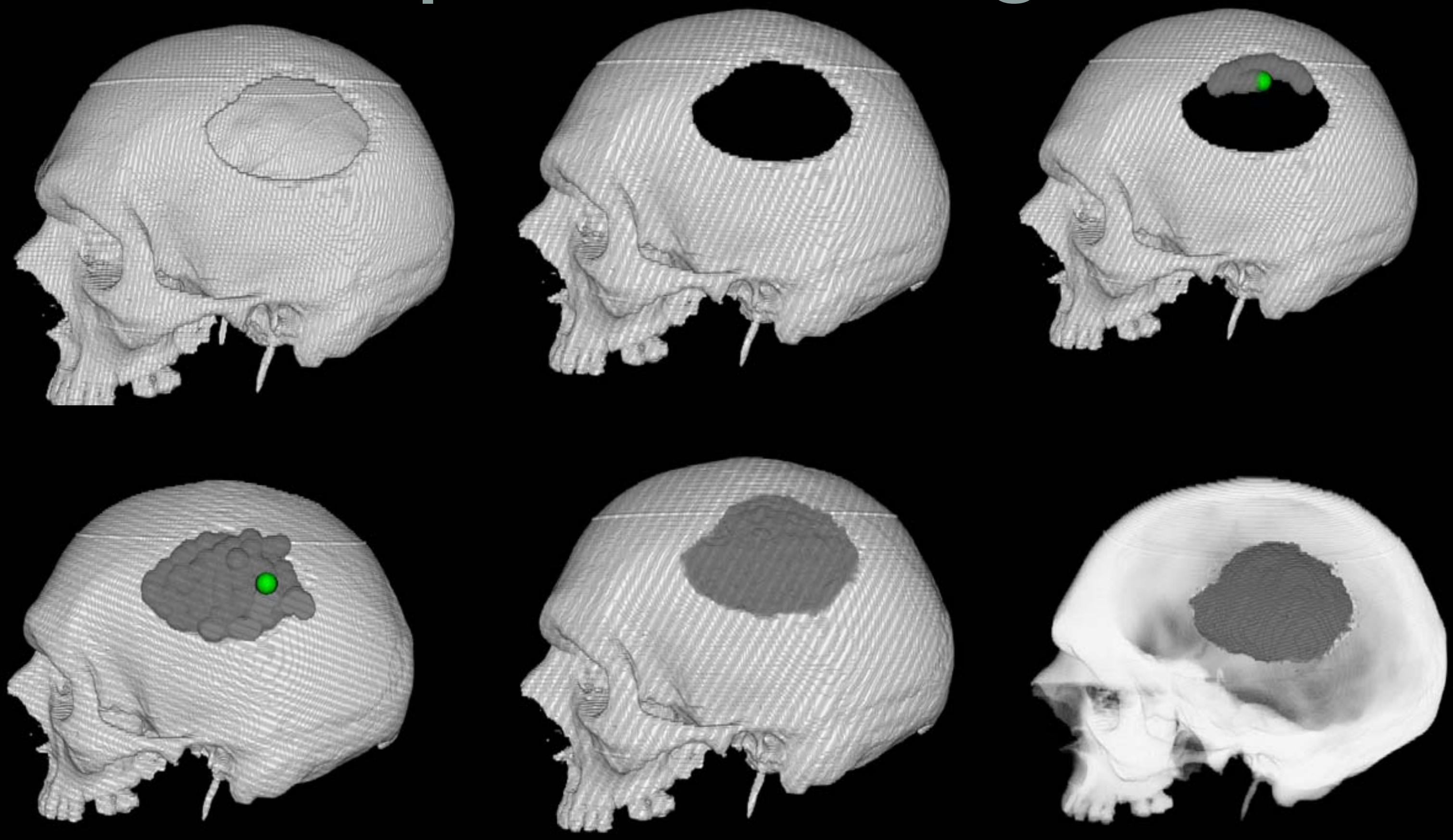
Implant Design



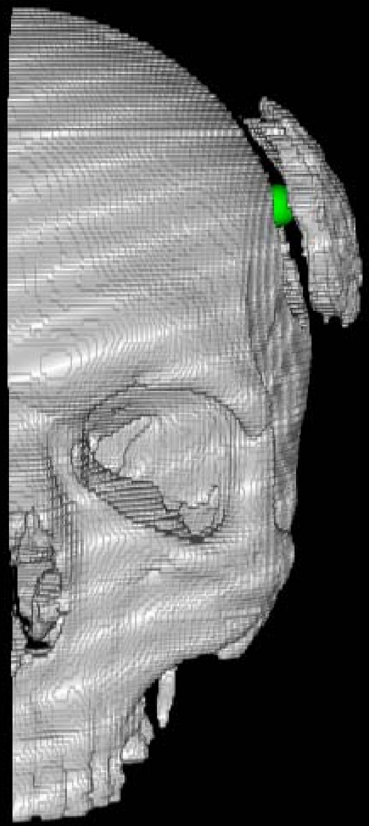
- Simulated defect

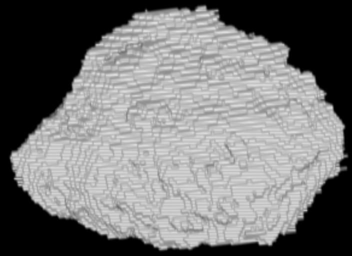
Implant Design



Implant Design

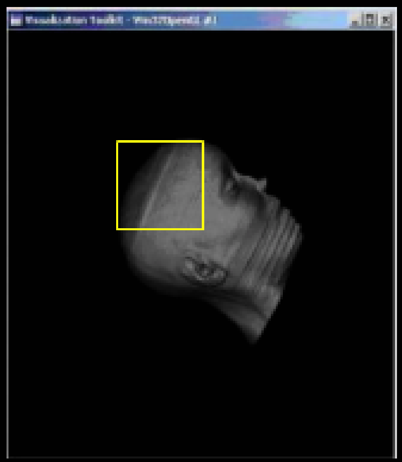
- Edge trimming



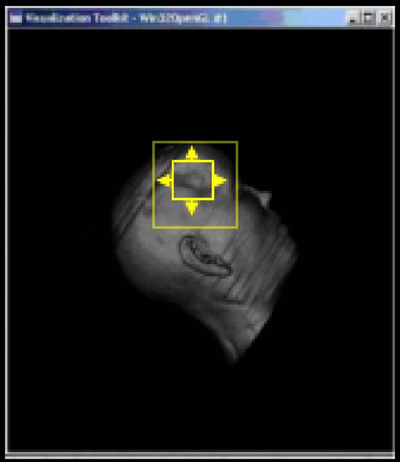


Bilateral Symmetry of the Skull

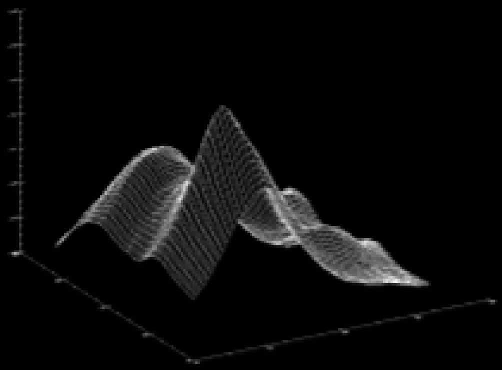
Research area



template



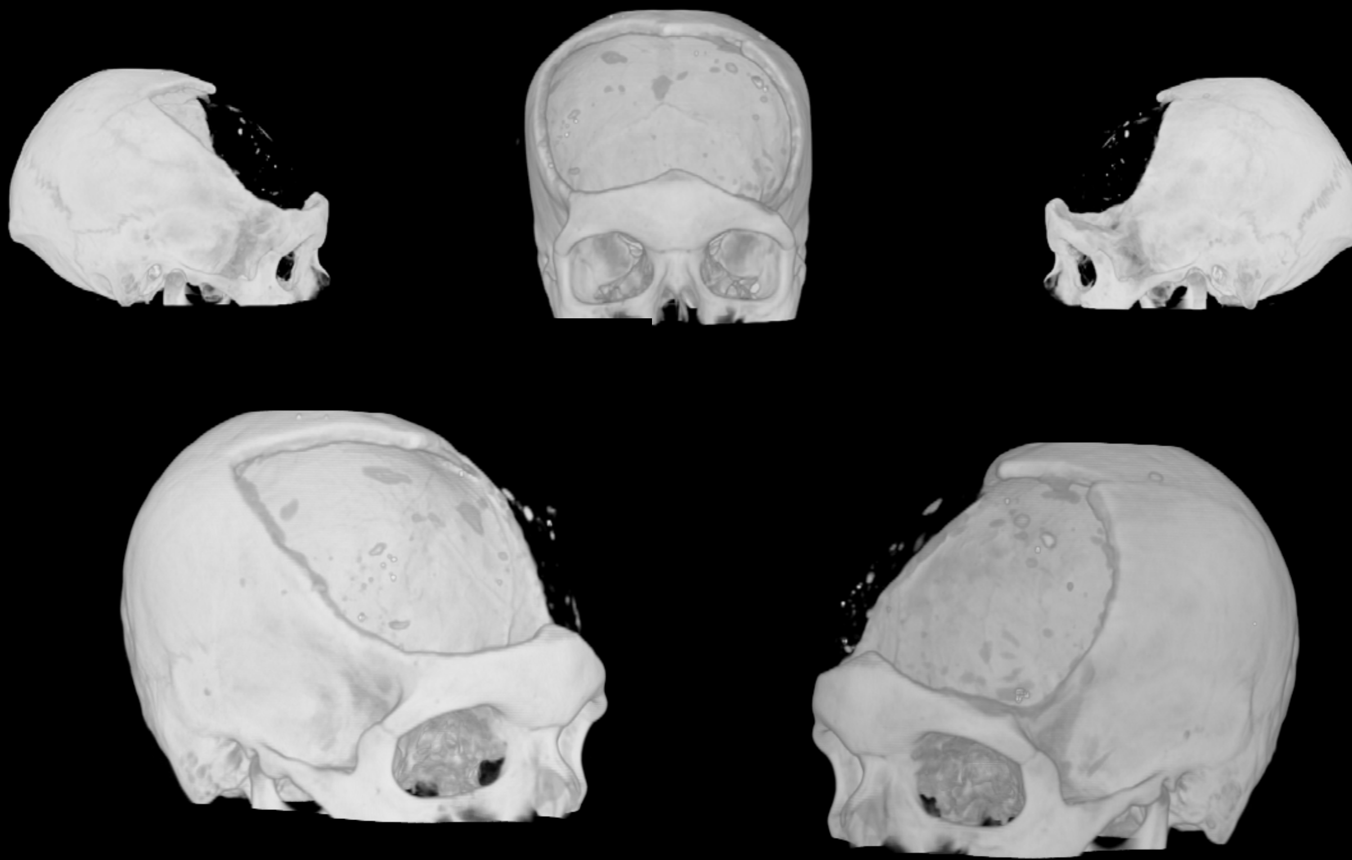
Cost function



- Split the skull at a symmetric plane
- Registration (translation, rotation, warping)
- Subtraction

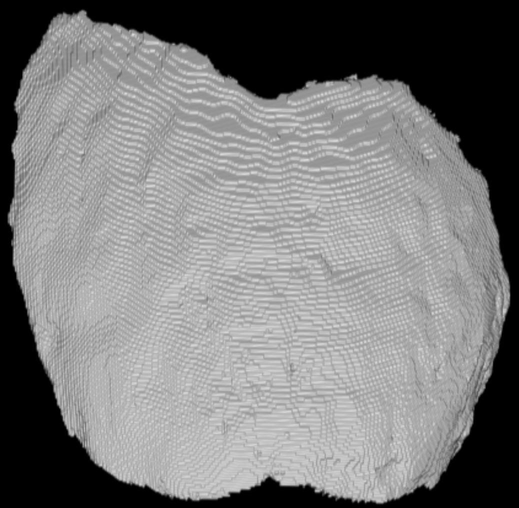
Implant Design

- Case 1: Patient CT data



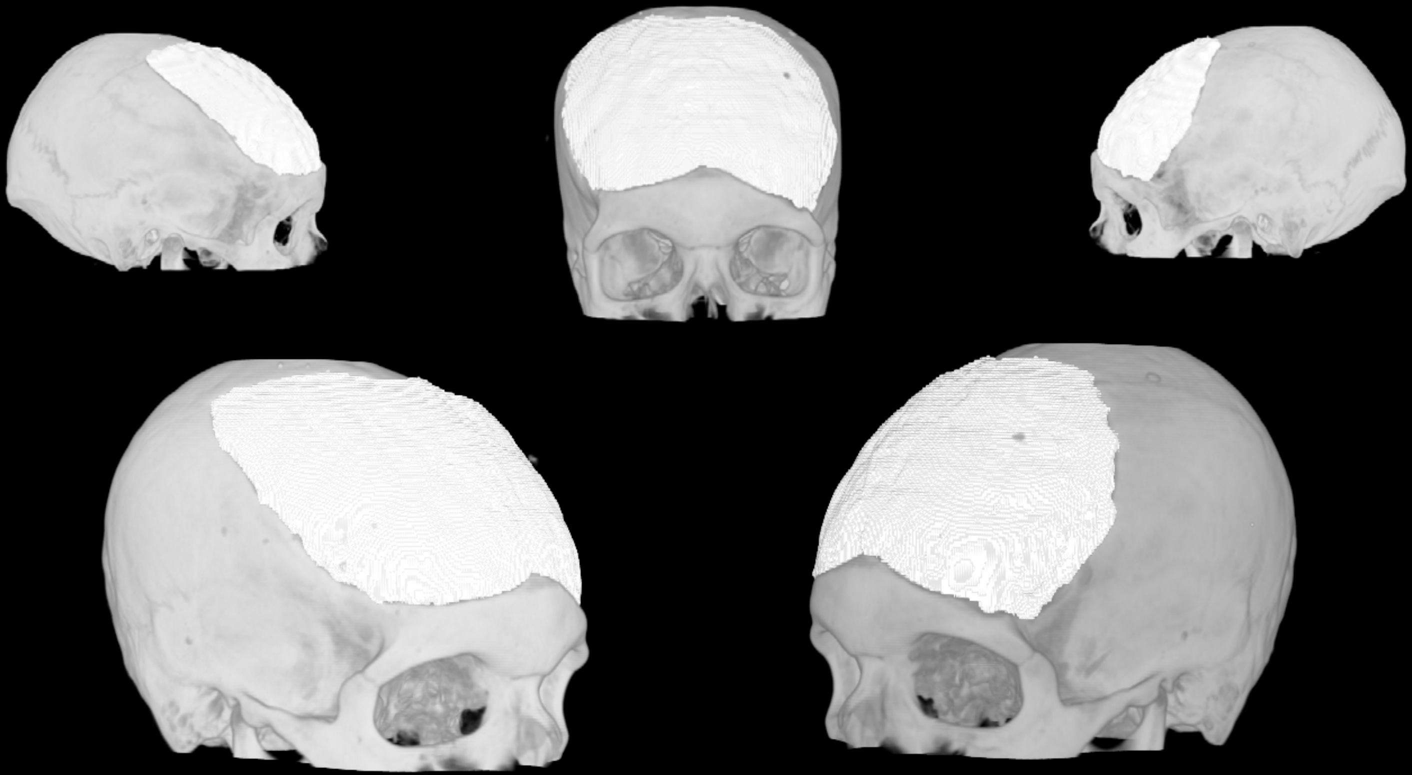
Implant Design

- Case 1: Implant



Implant Design

- Case 1:



Implant Design

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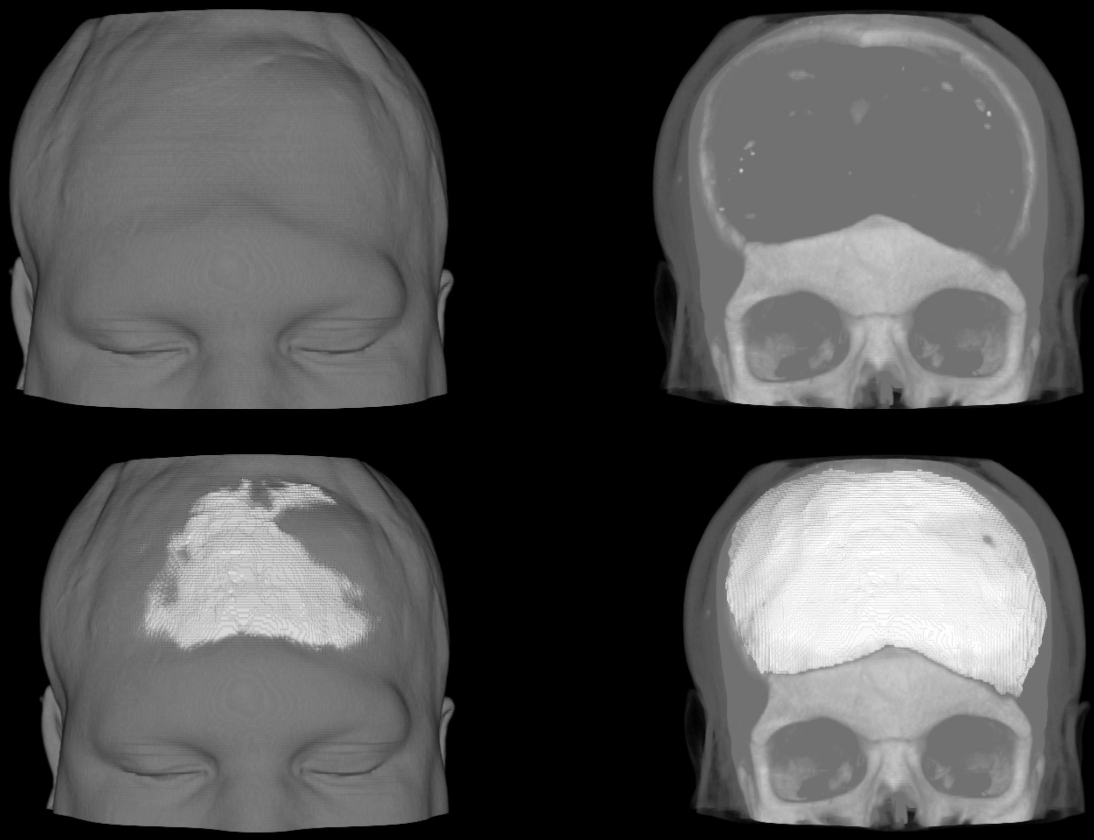

Implant Design

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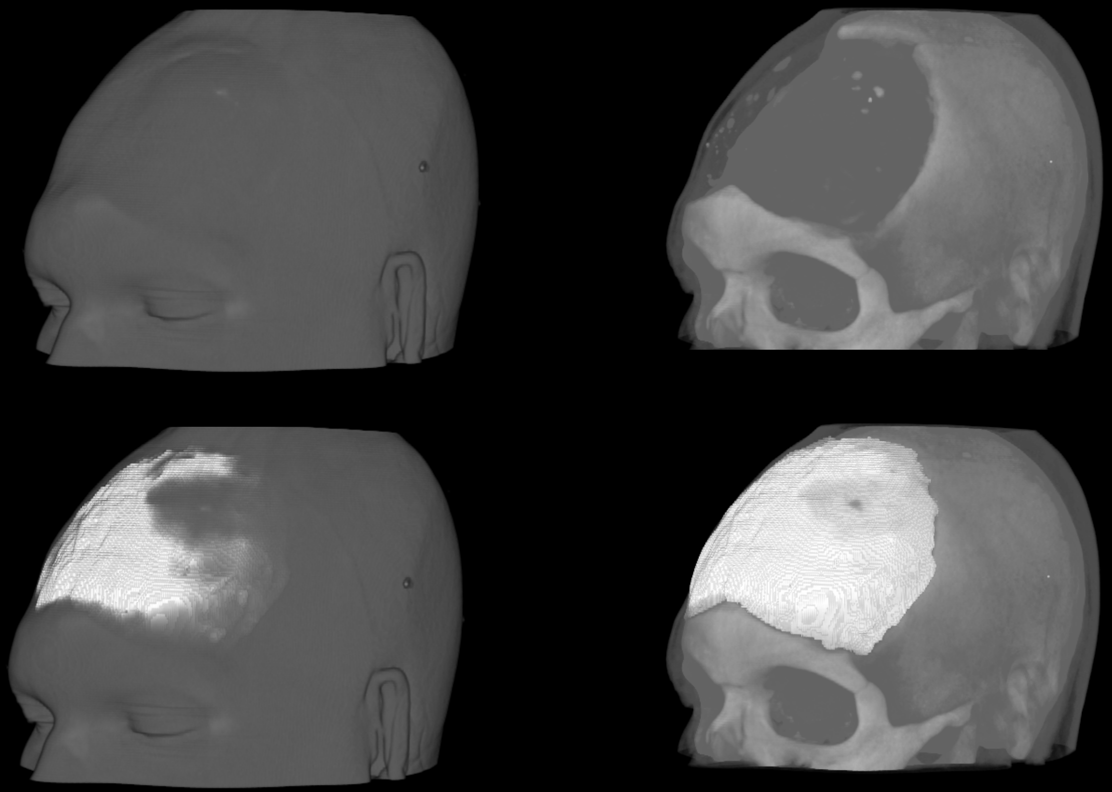

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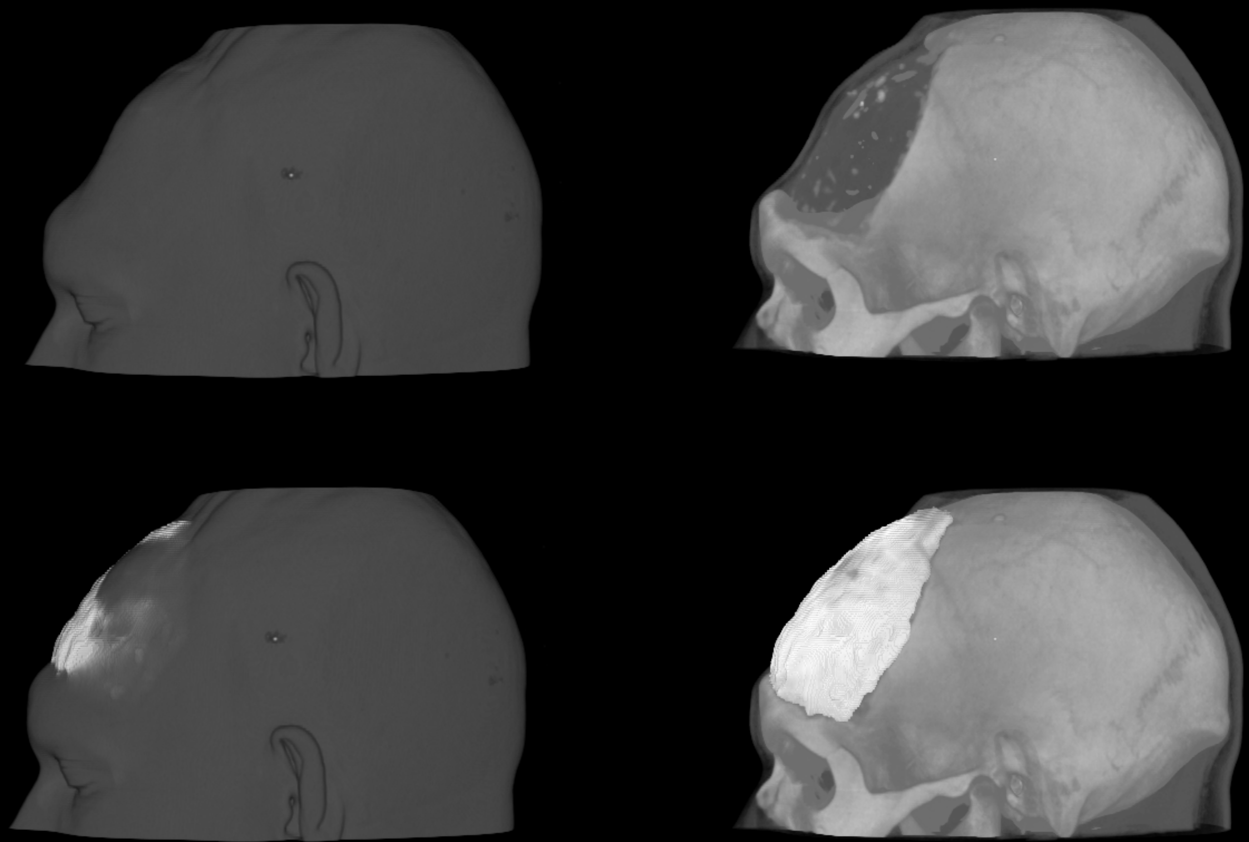

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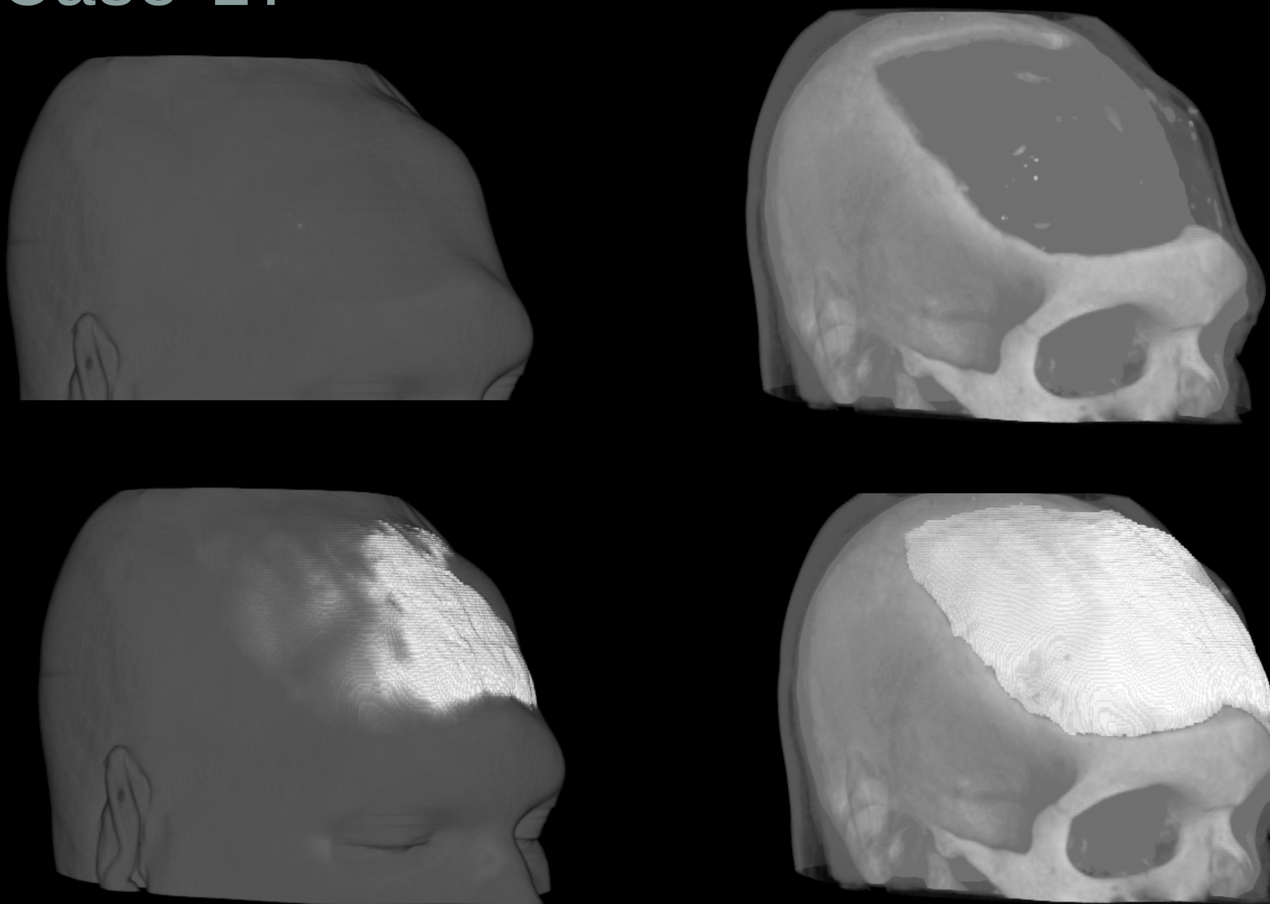

Implant Design

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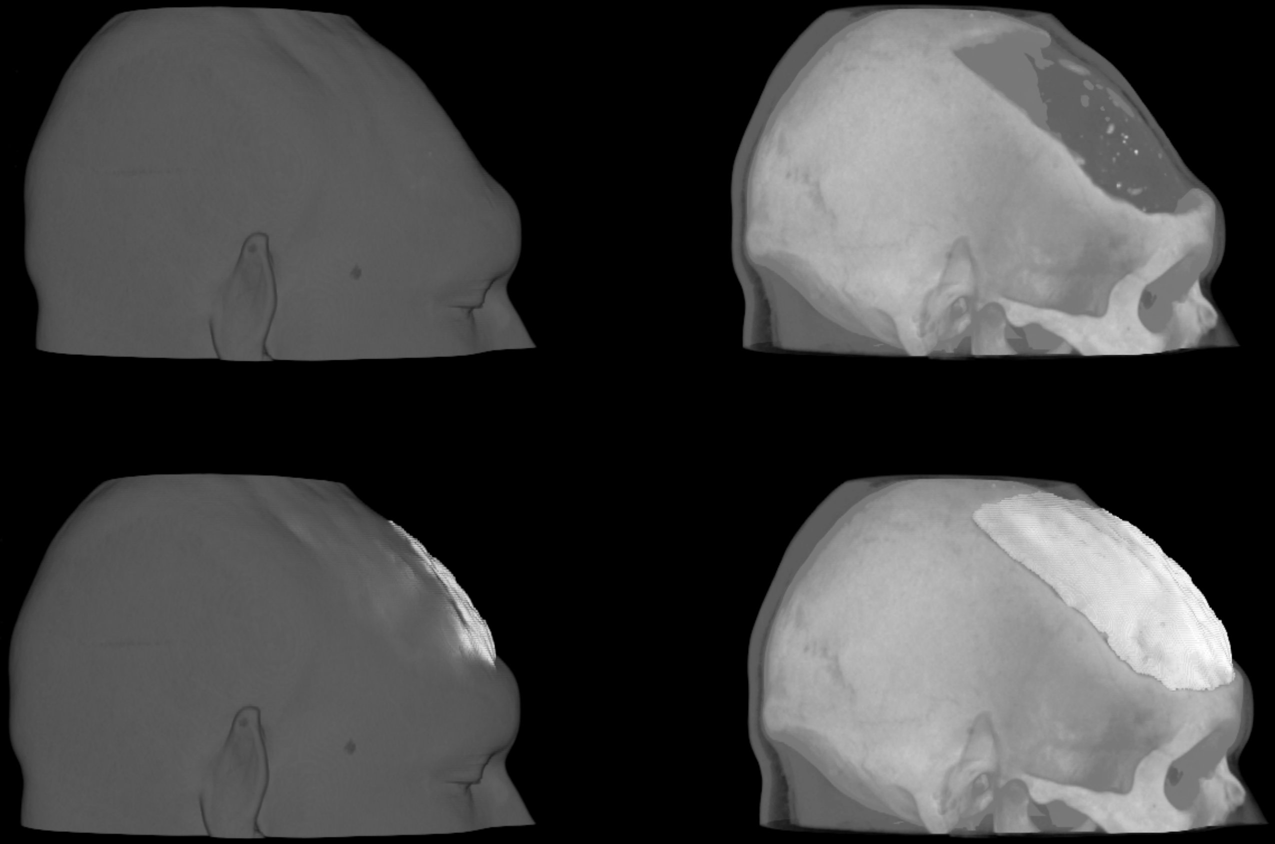

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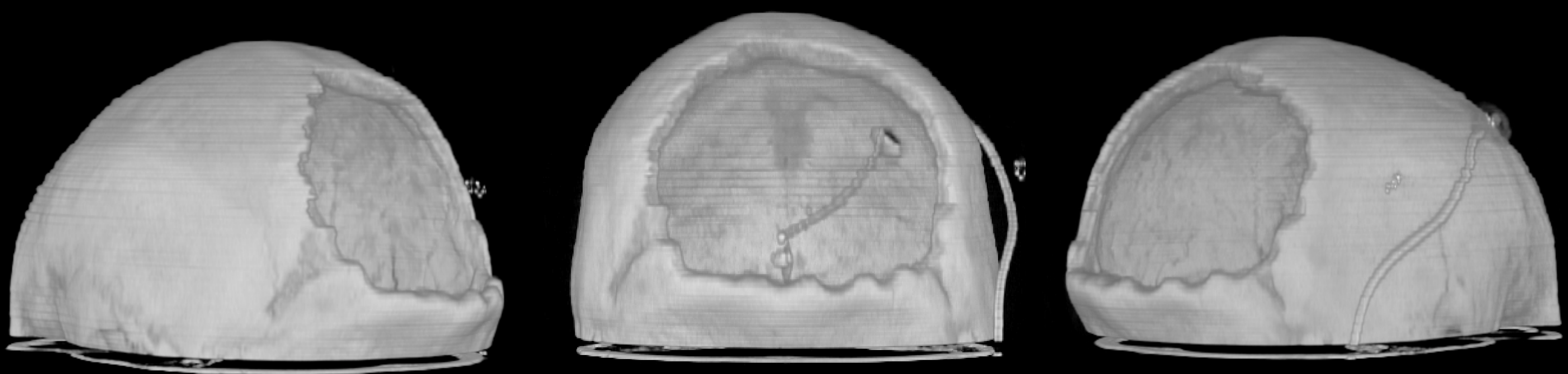
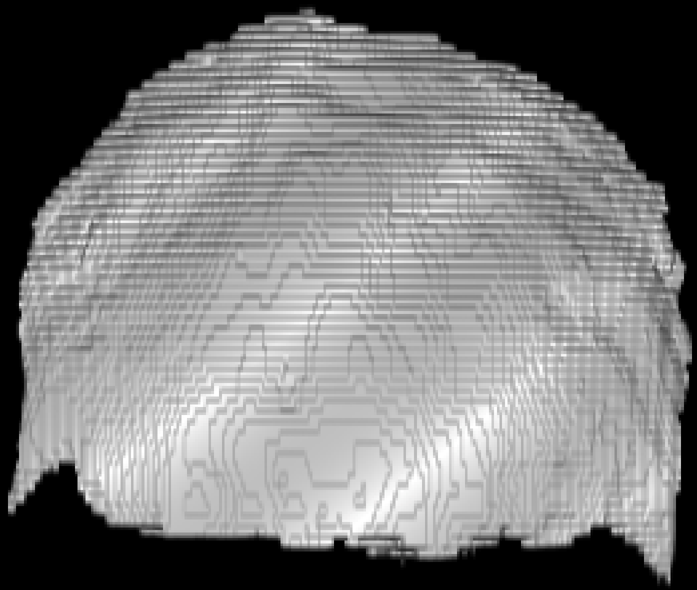
Implant Design

- Case 2:



Implant Design

- Case 2:



Implant Design

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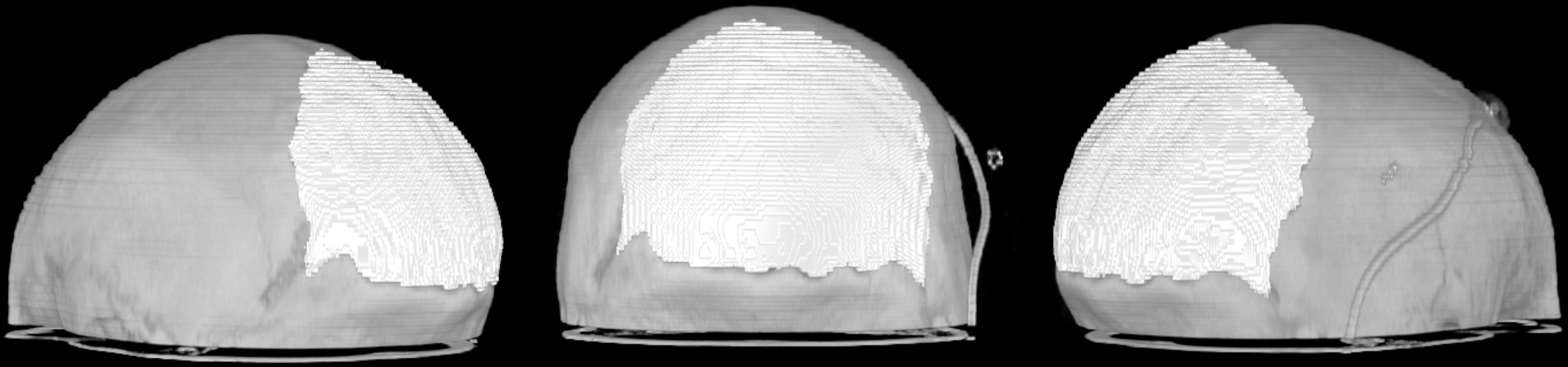
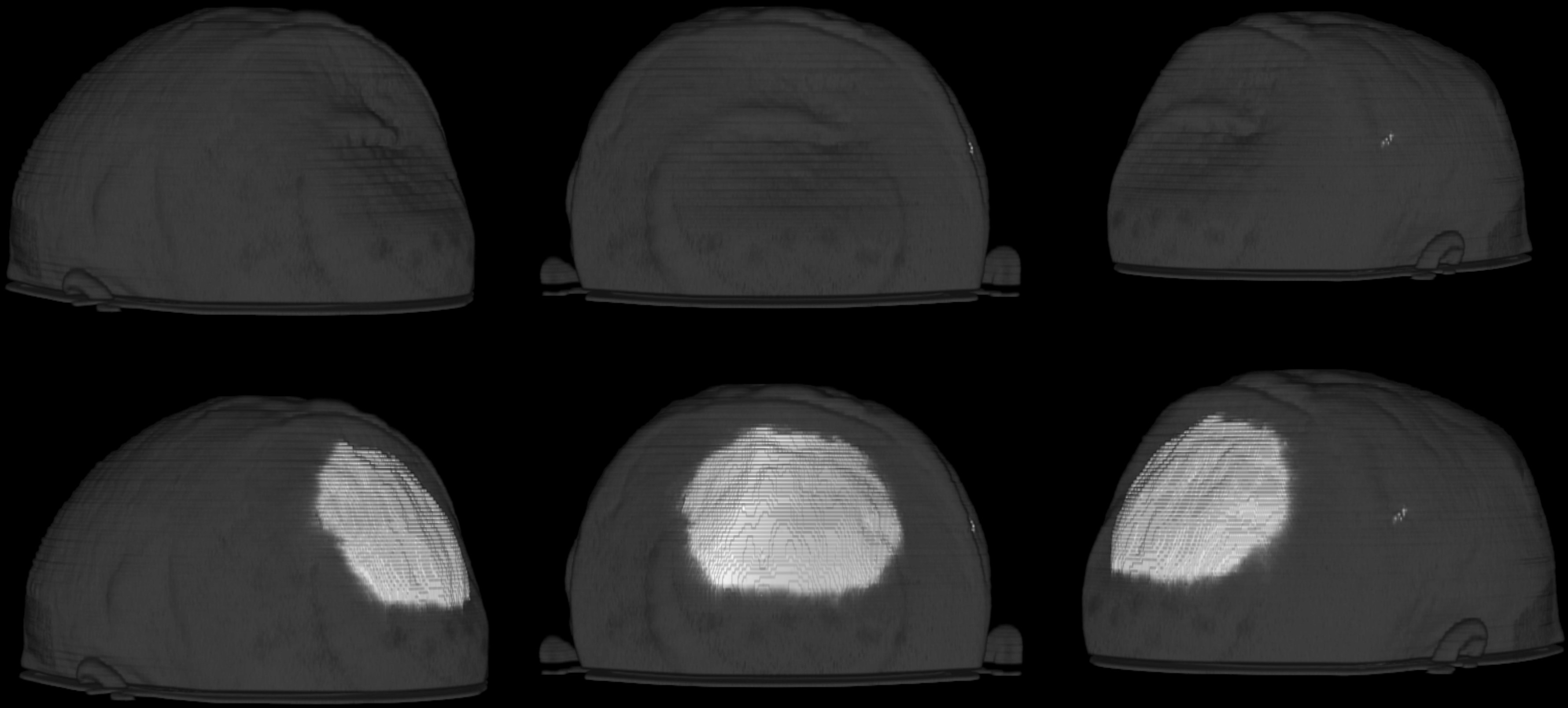


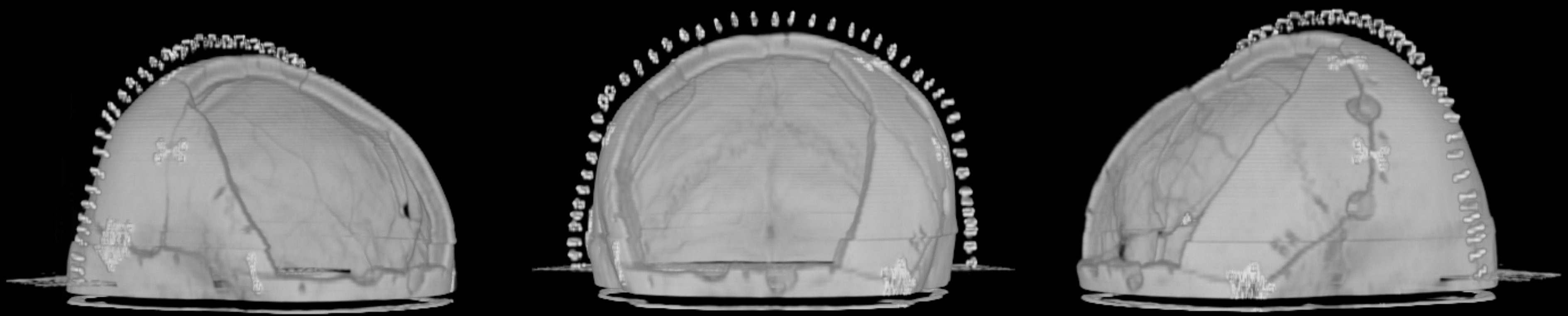
Implant Design

- Case 2:



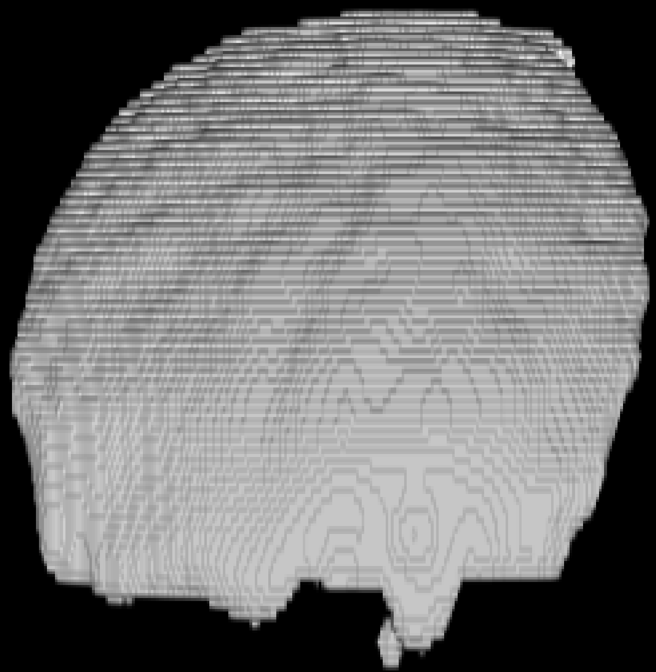
Implant Design

- Case 3:



Implant Design

- Case 3:



Implant Design

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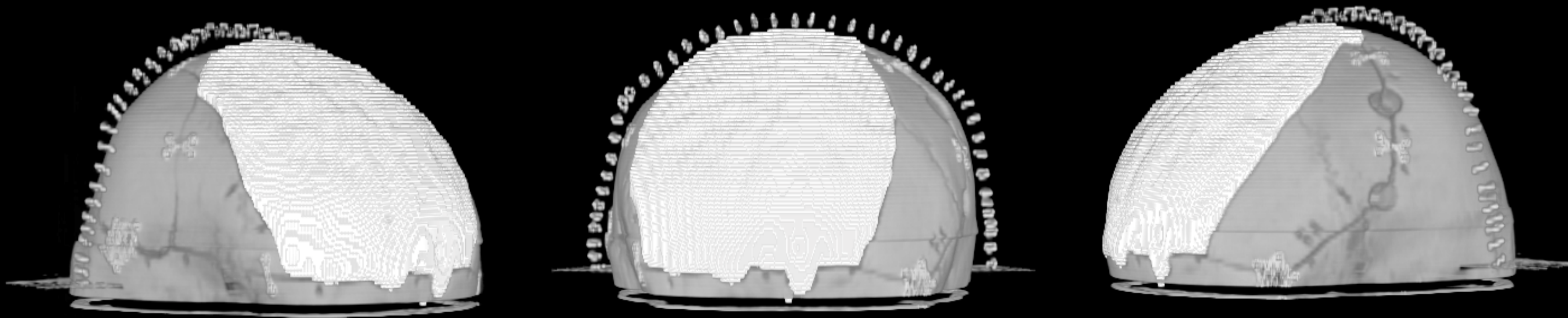

Implant Design

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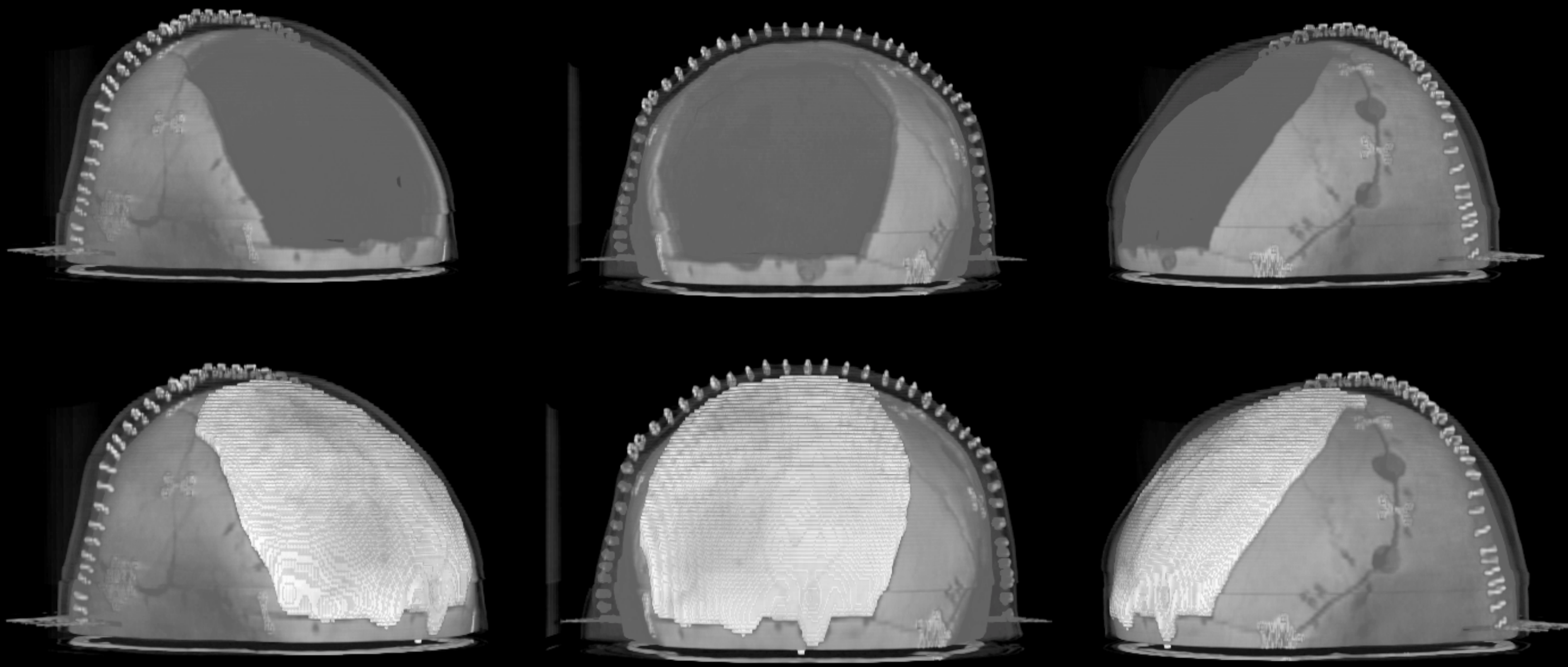
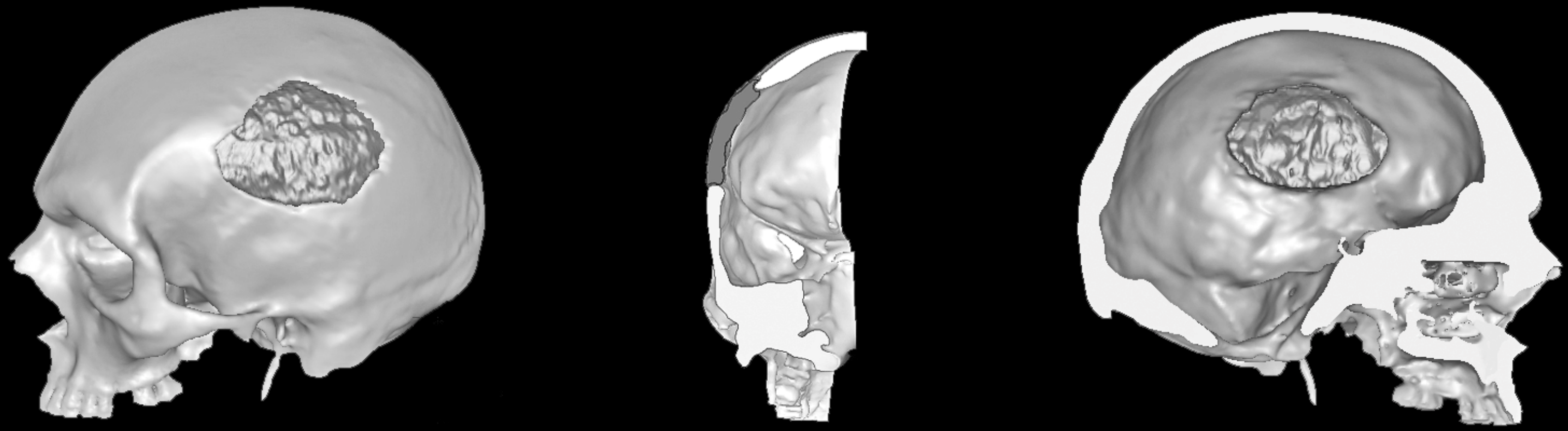
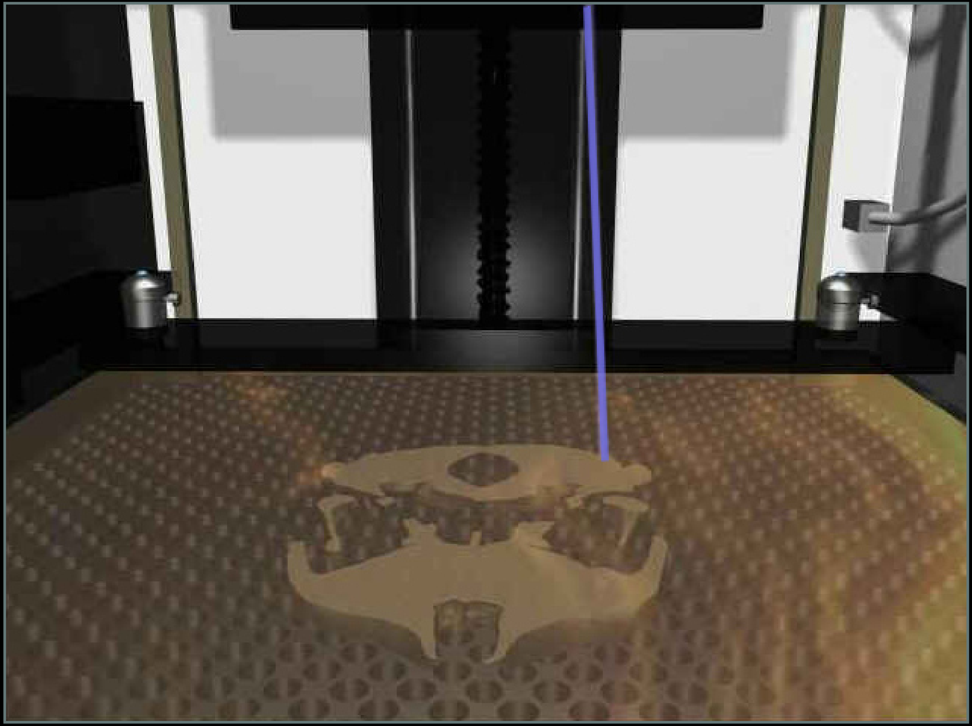


Implant Fabrication and Testing



Implant Fabrication and Testing



Stereolithography

Implant Fabrication and Testing

Implant Fabrication and Testing

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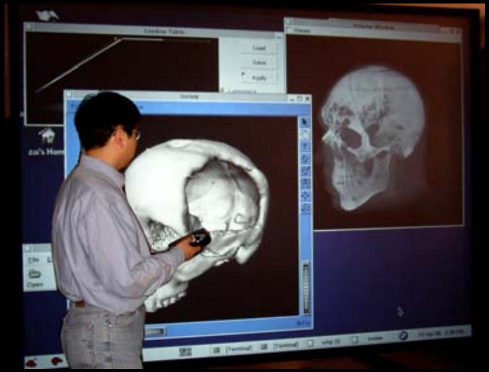
Components

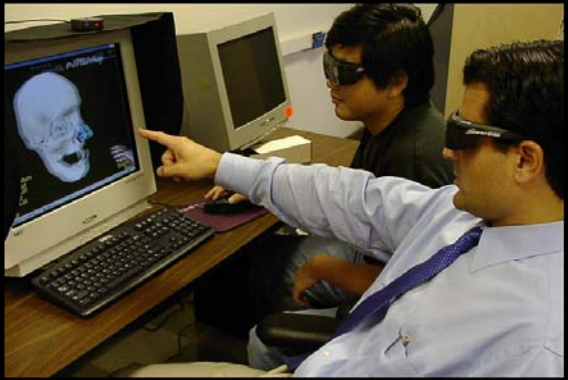
- Virtual reality display systems
- Immersive implant modeling system
- Implant design
- Surgical consultation over networks

Surgical Consultation and Collaboration

- Adaptive networking
  - Quanta: the Quality of Service Adaptive Networking Toolkit
- Tele-immersive implant modeling
  - PARIS – C-Wall
- Distributed volume visualization
  - Clusters of powerful graphics computers are used to distribute very large volumes for parallel rendering.
  - Resultant images are stitched together and streamed over the network to PARIS, C-Wall, and Physician's Personal VR Display.
  - Cluster can therefore act as a powerful shared resource amongst physicians at many locations.
  - Higher speed networks (such as National Lambda Rail, StarLight and Internet-2) will enable higher quality real time image transfer with lower latencies.

Surgical Consultation and Collaboration





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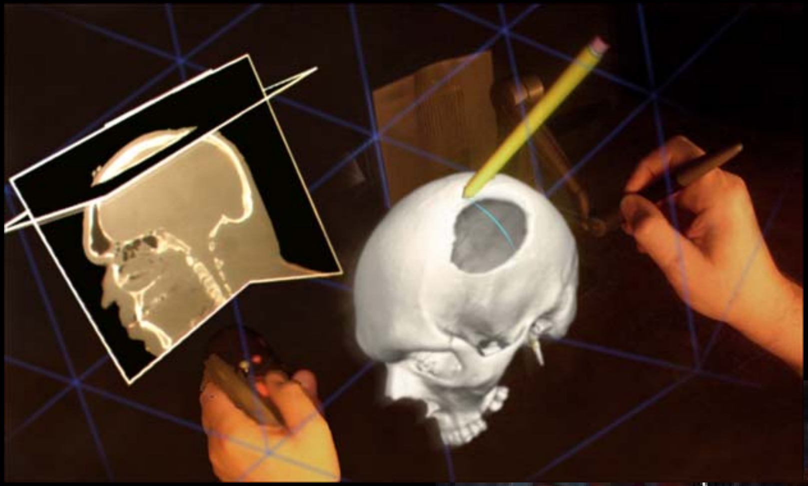
VR Systems

- Personal Augmented Reality Immersive System (PARIS)
- Configurable Wall (C-Wall)
- Physician's Personal VR Display

PARIS

- Based on PC
- Augmented reality
- Haptic feedback

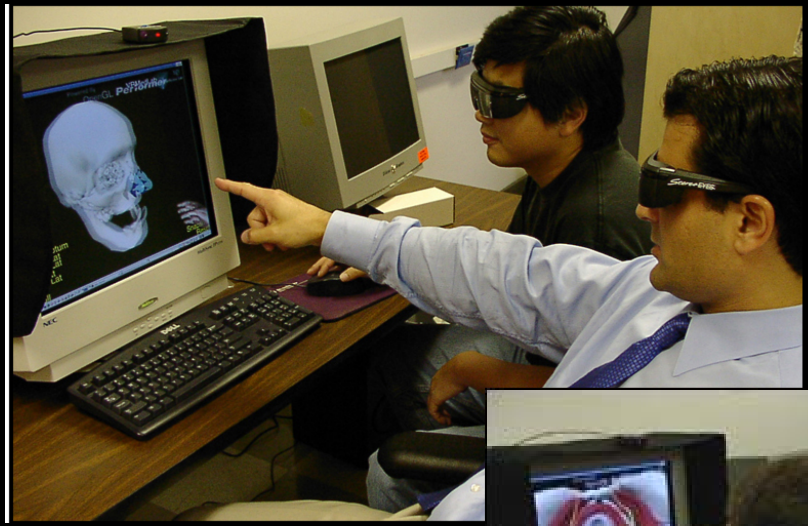


Configurable-Wall (C-Wall)

- Small group consultation

Physician's Personal VR Display

- Physician's desktop
- Hardware platform and operating system
- Graphics card and stereo display
- Software development tools
- 3D input devices



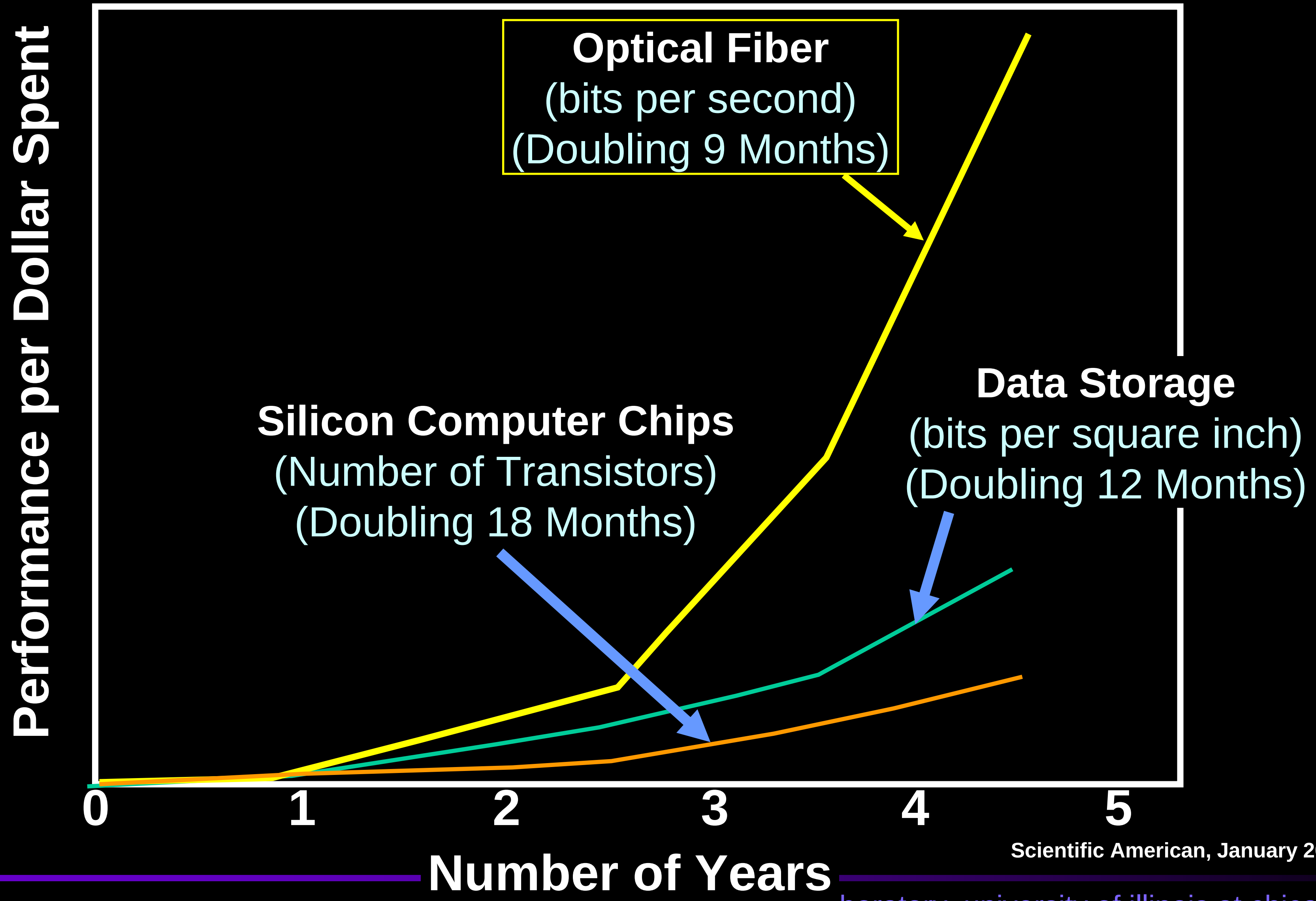
Applications

- Consultation
- Pre-operative planning
- Implant design
- Surgical simulation
- Post operative evaluation
- Education
- Large-scale health emergencies

Future Opportunities

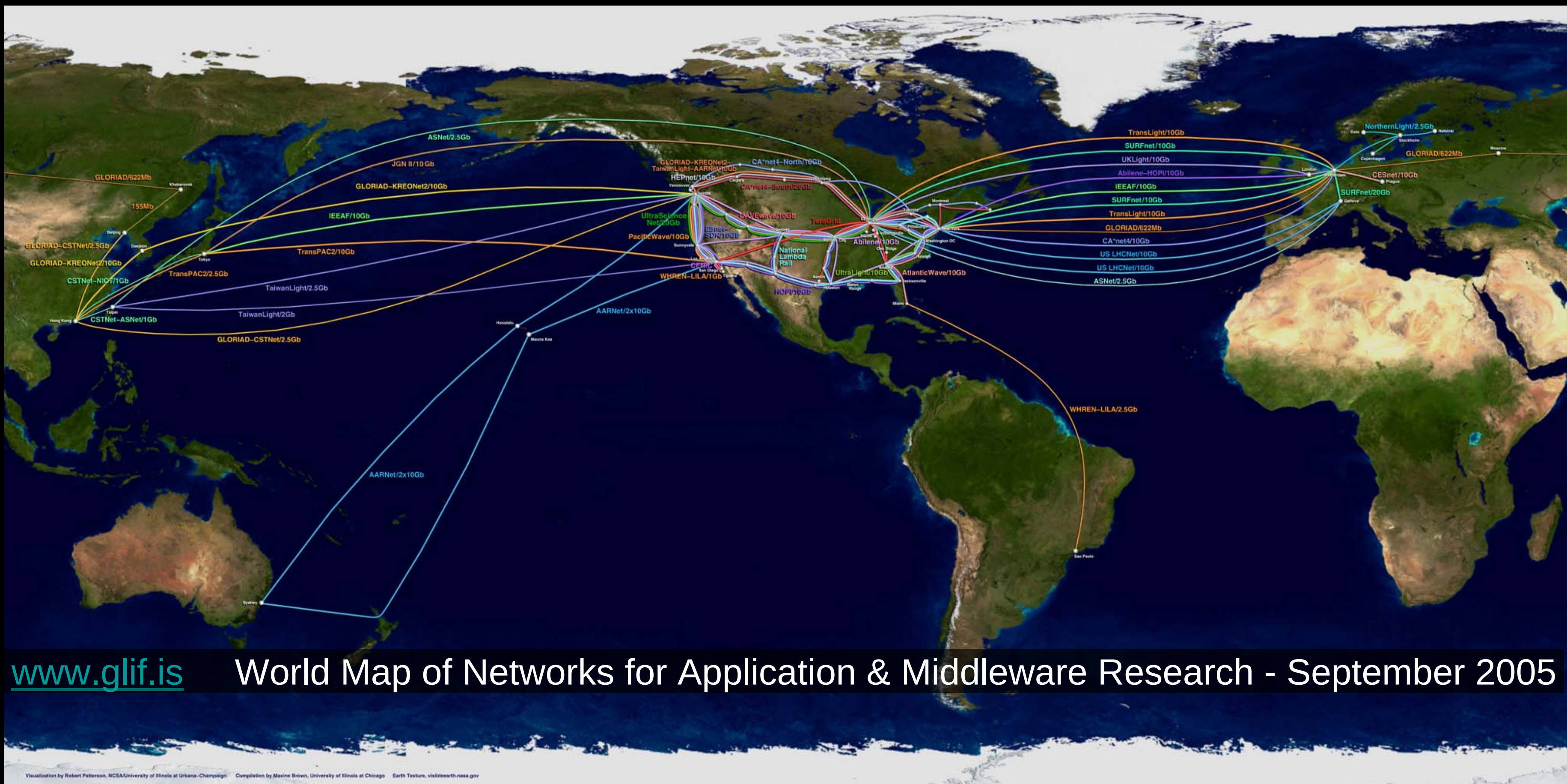
Jason Leigh, Zhuming Ai

Performance per Dollar between Optical Fiber, Silicon and Data Storage



Scientific American, January 2001

StarLight & Global Lambda Integrated Facility Persistent Optical Networking Infrastructure for Rapid Distribution of Large Scale Instrumentation Data



www.glif.is World Map of Networks for Application & Middleware Research - September 2005

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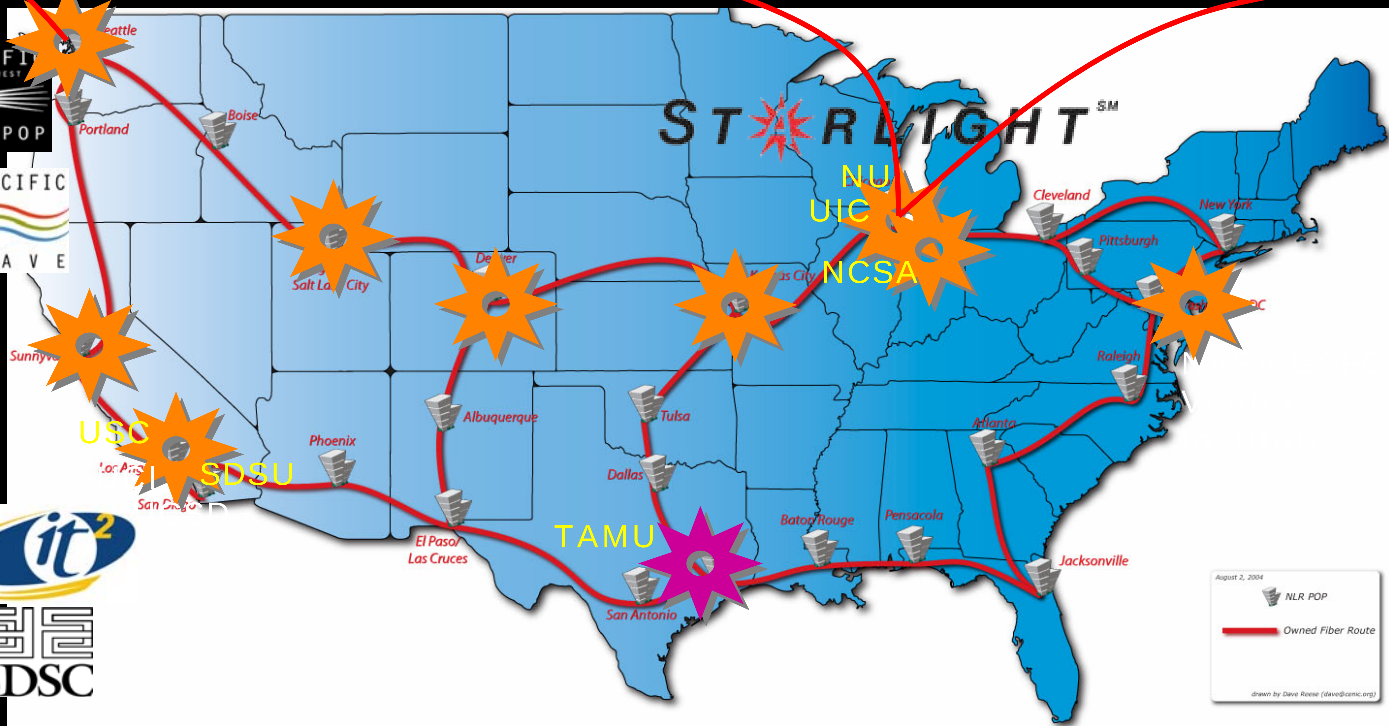
OptIPuter

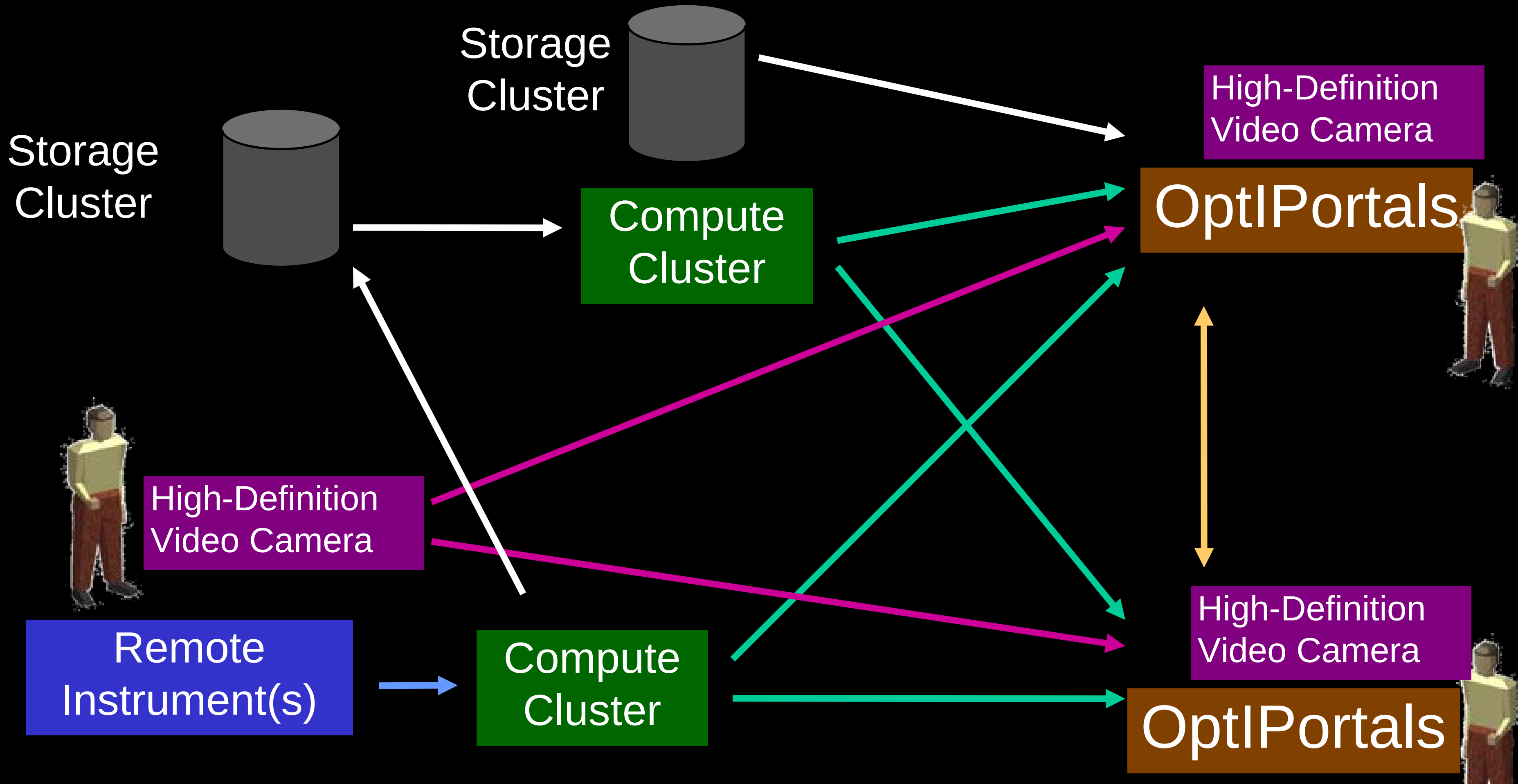
10GE CAVEwave on the National LambdaRail

The OptIPuter exploits a new world in which the central architectural element is optical networking – creating *supernetworks*



CAVEwave™ is the University of Illinois at Chicago (UIC) Electronic Visualization Laboratory's very own 10 Gigabit wavelength on the NLR infrastructure, connected to the University of Washington in Seattle and UCSD in San Diego, enabling OptIPuter experiments. It was recently extended to the DC area to connect with NASA GSFC and Venter Institute

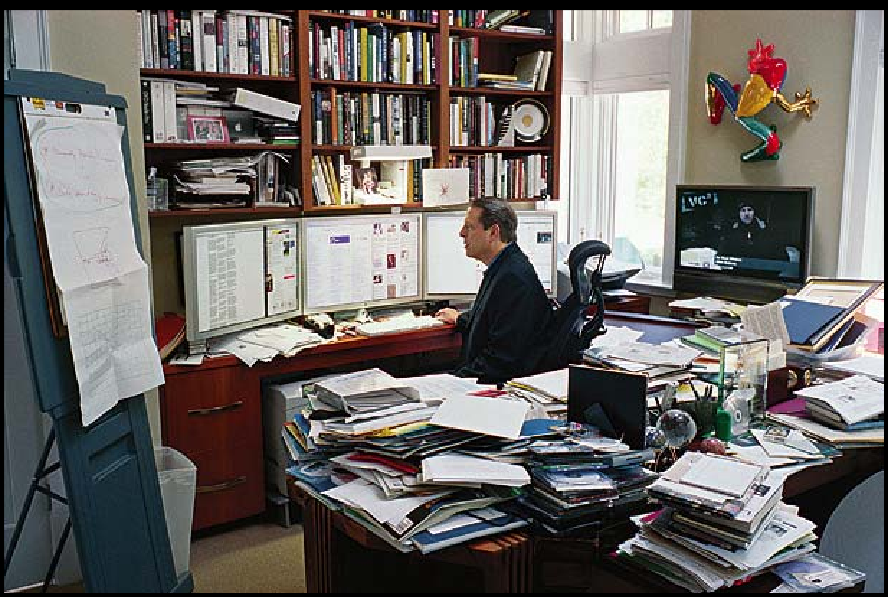
OptIPuter



Main challenge is in building the MIDDLEWARE & APPLICATIONS

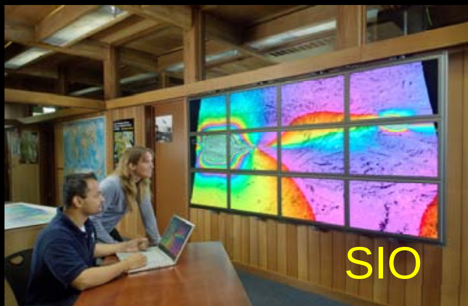
Cyber-Commons and Cyber-Mashups

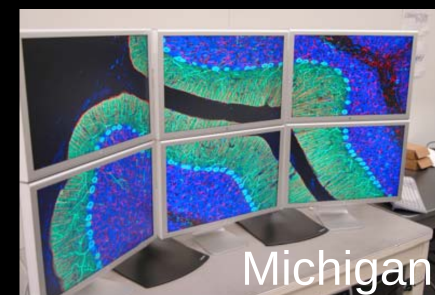
- Cyber-Commons: Environments with scalable displays that enable rich interaction between people and information.
- Cyber-Mashups: Virtual environments for merging data from Cyber-Observatories to create new discoveries.



100 Million Pixel Display Wall

The OptIPuter Global Cyber Community





www.optiputer.net

www.evl.uic.edu/cavern/glvf/

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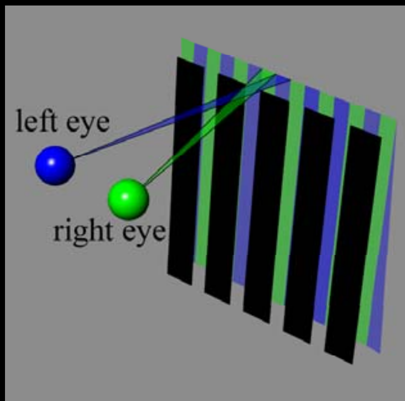
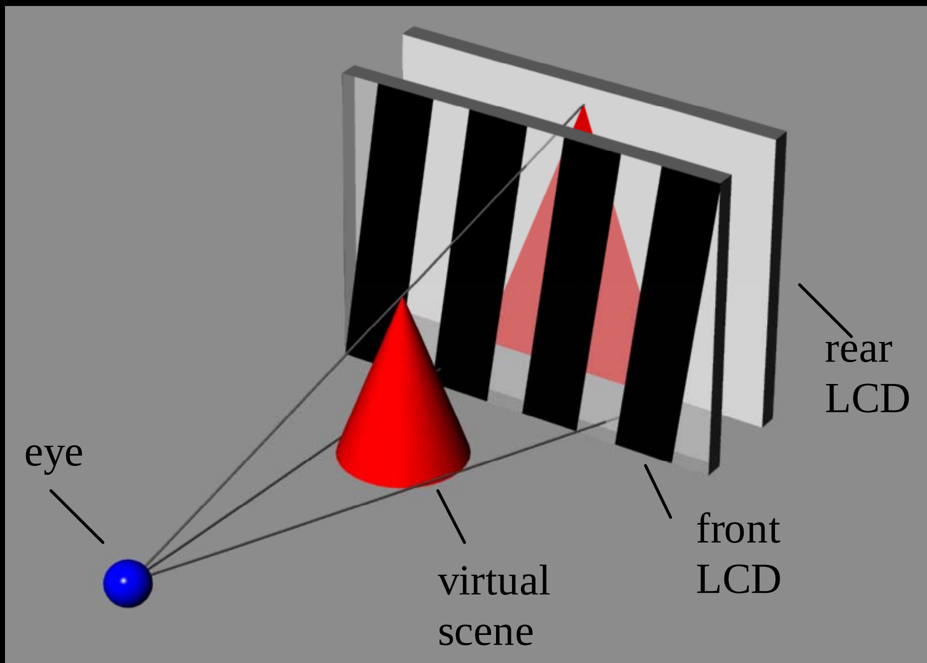
Varrier - Autostereo Display (2004)



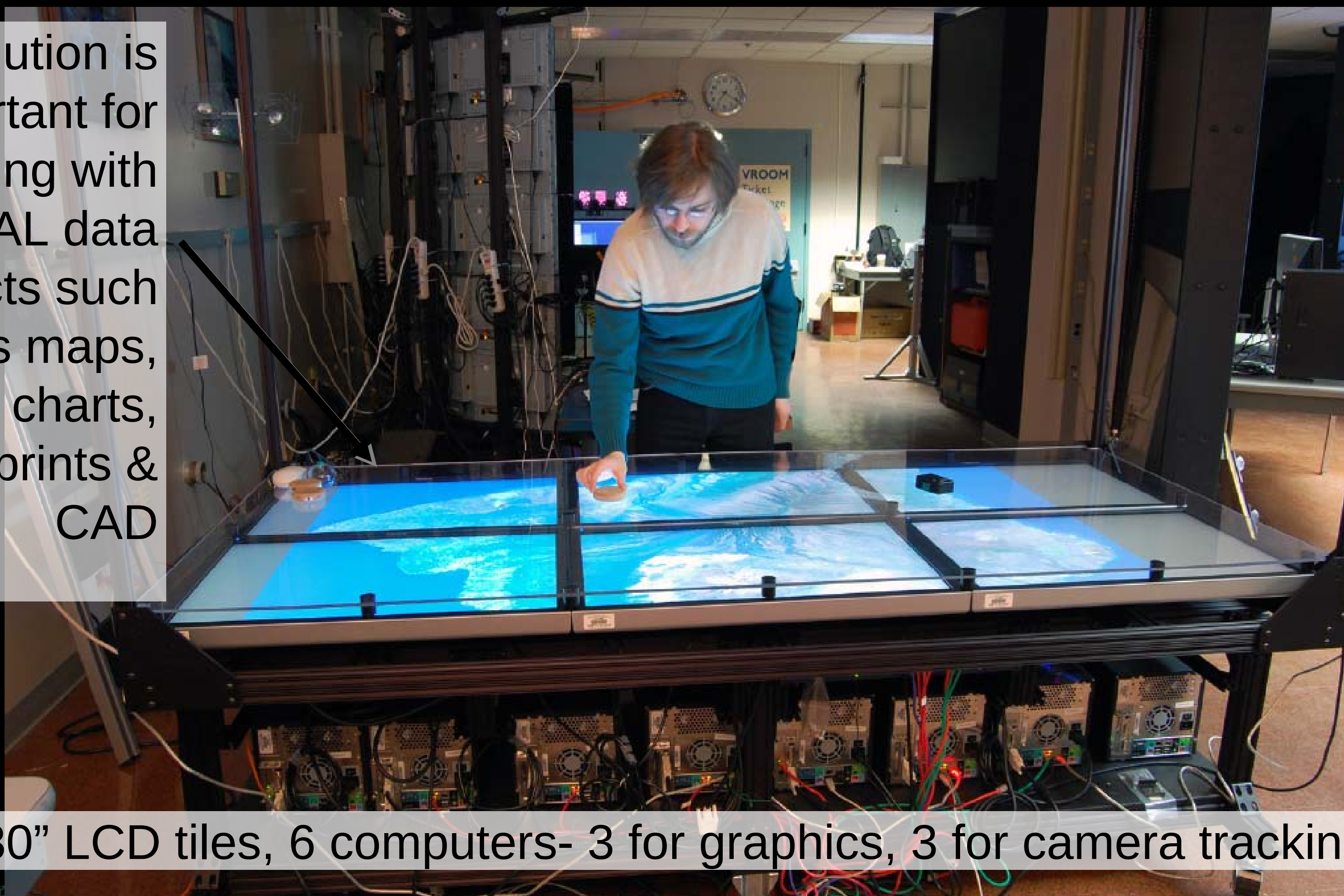
Merging Mono and Stereo : Dynallax (2006)



Enables mono, stereo and a combination

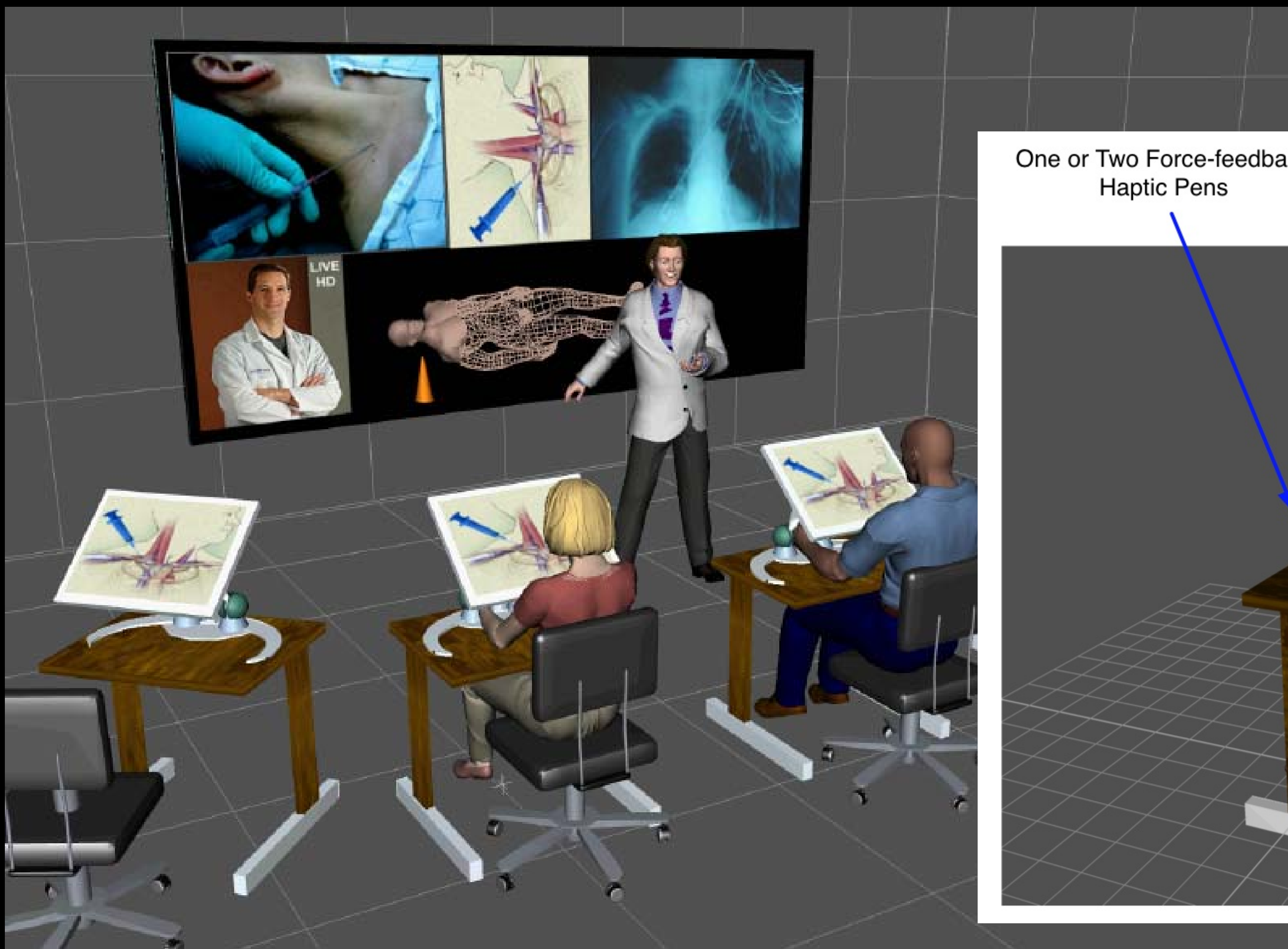
Alternative Interaction Modalities
LambdaTable (2005)

Resolution is important for working with REAL data products such as maps, charts, blueprints & CAD

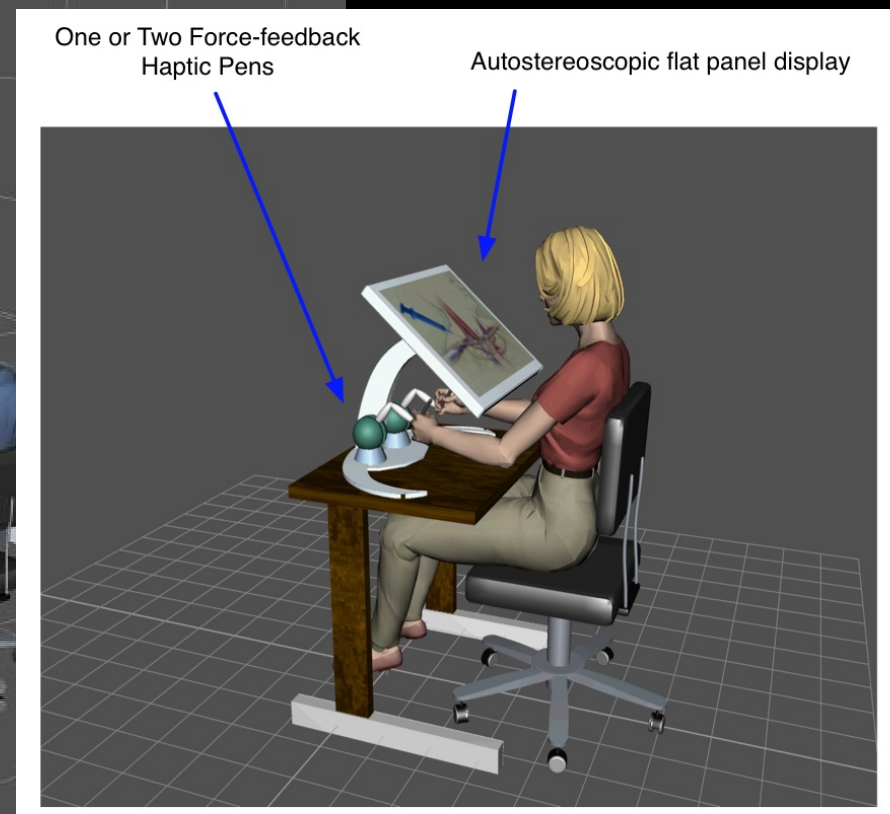


30” LCD tiles, 6 computers- 3 for graphics, 3 for camera tracking

Cyber-environment for Medical Research and Simulation of the Future



VirtuaTouch



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- National Library of Medicine / National Institutes of Health Award N01-LM-3-3507

- NSF Awards CNS 0703916 , 0420477; ANI 0225642

- For more information visit:
  - www.evl.uic.edu