Robotic Surgery and Surgical Simulation

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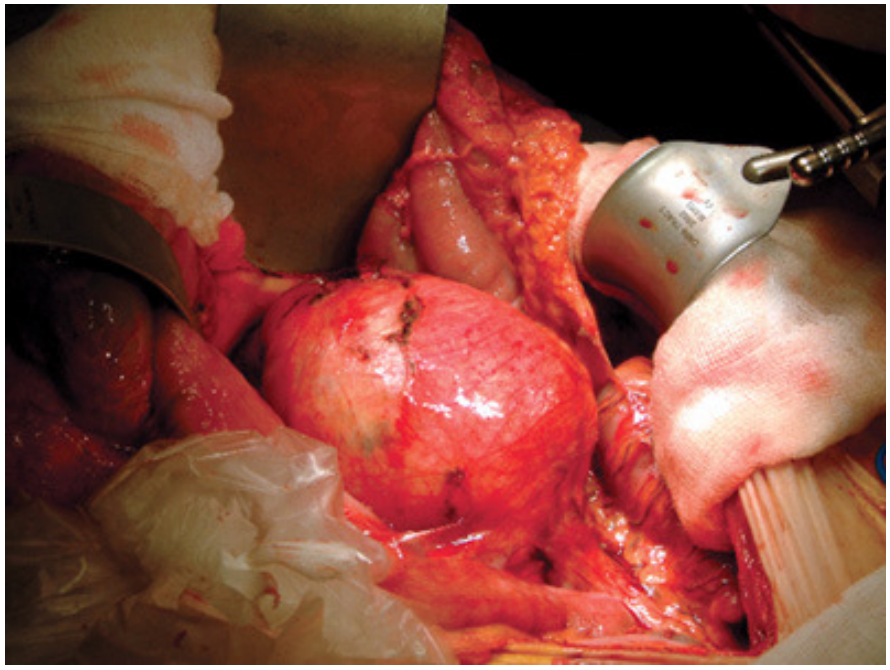
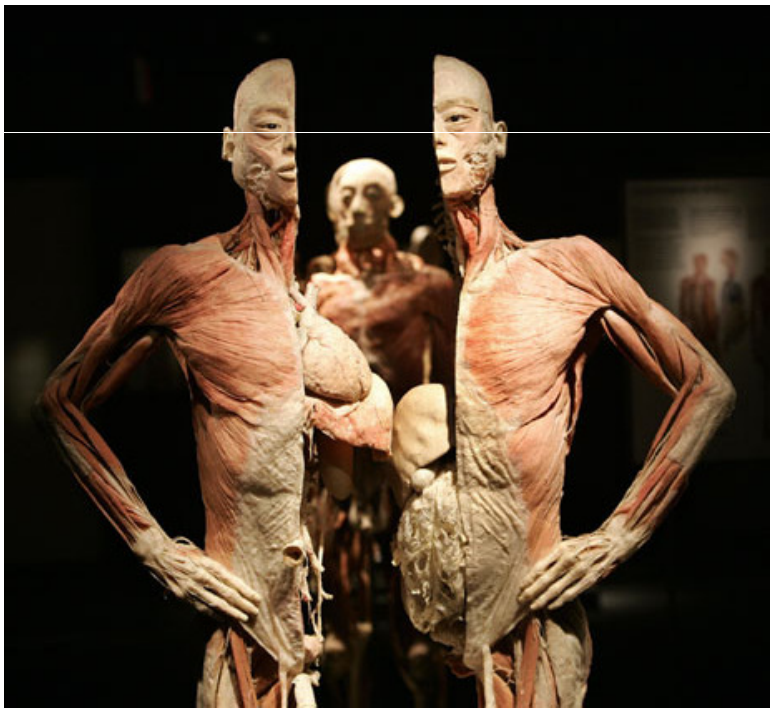
Nicholson Center for Surgical Advancement

- **Surgical Education**
  - **Robotic Surgery**
  - **Laparoscopic Techniques**
  - **Orthopedic Equipment**
- **Surgical Research**
  - **Robotic Surgery**
  - **Telesurgery**
  - **Simulation Applications**

Open Surgery

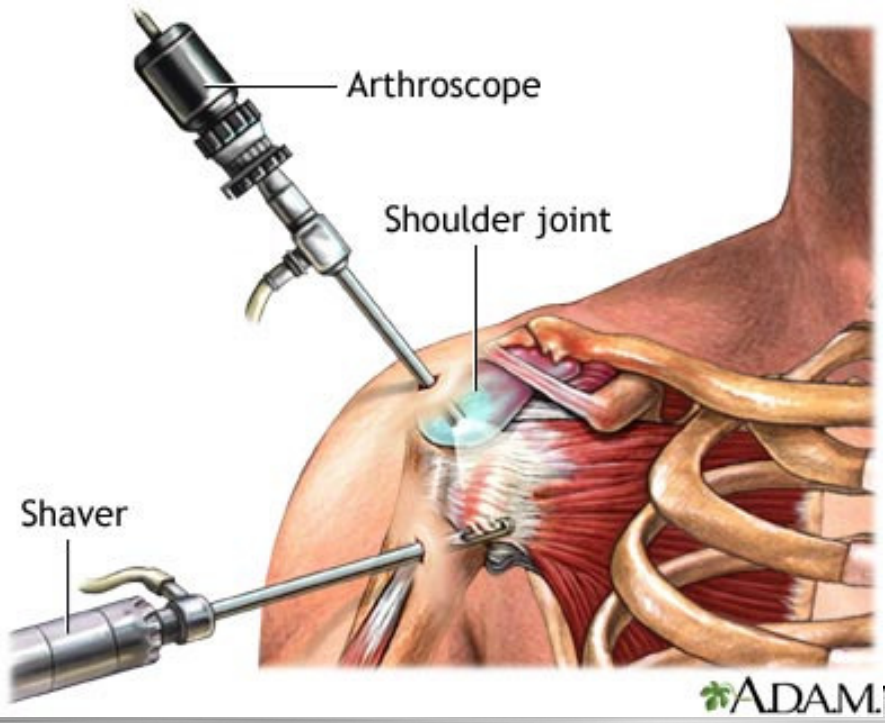
- "An *open surgery* means cutting skin and tissues so the surgeon has a direct access to the structures or organs involved. The structures and tissues involved can be seen and touched, and they are directly exposed to the air of the operating room."

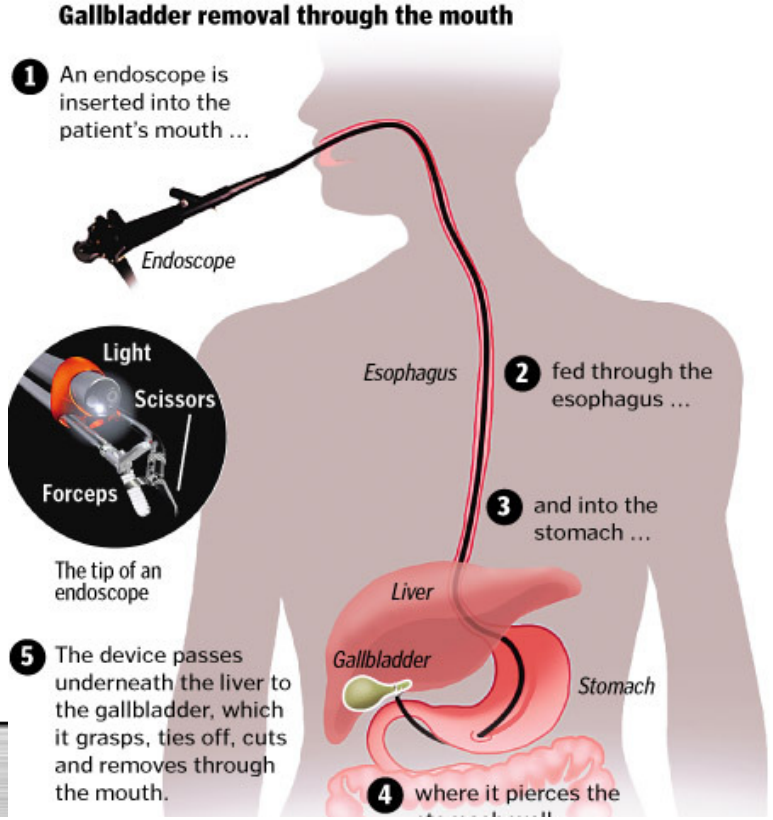




Minimally Invasive Surgery

- "A *minimally invasive procedure* is less invasive than open surgery used for the same purpose. It typically involves use of laparoscopic devices and remote-control manipulation of instruments with indirect observation of the surgical field through an endoscope or similar device, and is carried out through the skin or through a body cavity or anatomical opening. "



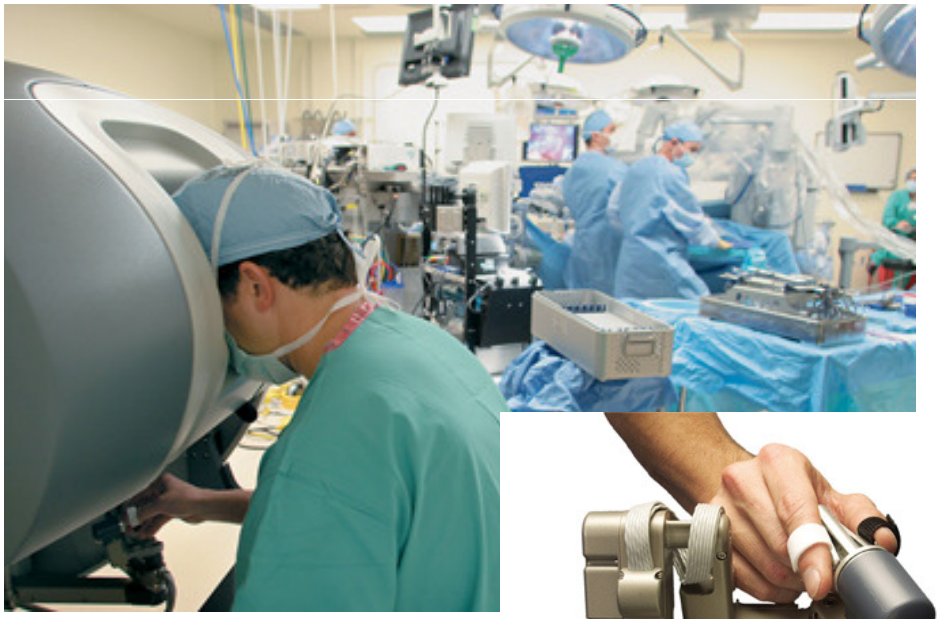


Laparoscopic Surgery

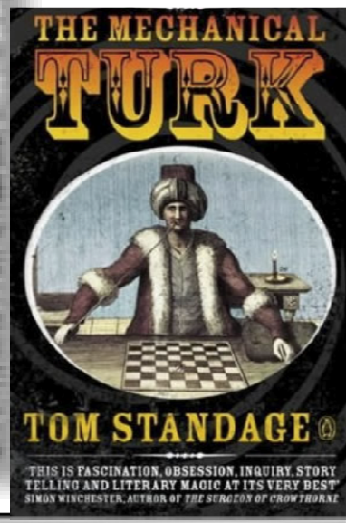
- “A type of minimally invasive surgery in which a small incision is made in the abdominal wall through which an instrument called a laparoscope is inserted to permit structures within the abdomen and pelvis to be seen. The abdominal cavity is distended and made visible by the instillation of absorbable gas, typically, carbon dioxide.”

Robotic Surgery

- “Robot-assisted surgery was developed to overcome limitations of minimally invasive surgery, Instead of directly moving the instruments the surgeon uses a computer console to manipulate the instruments attached to multiple robot arms. The computer translates the surgeon’s movements, which are then carried out on the patient by the robot.”



Mechanical Turk, 1770



http://en.wikipedia.org/wiki/The_Turk

Early Robotic Surgical Systems

AESOP: Automated Endoscopic System for Optimal Positioning

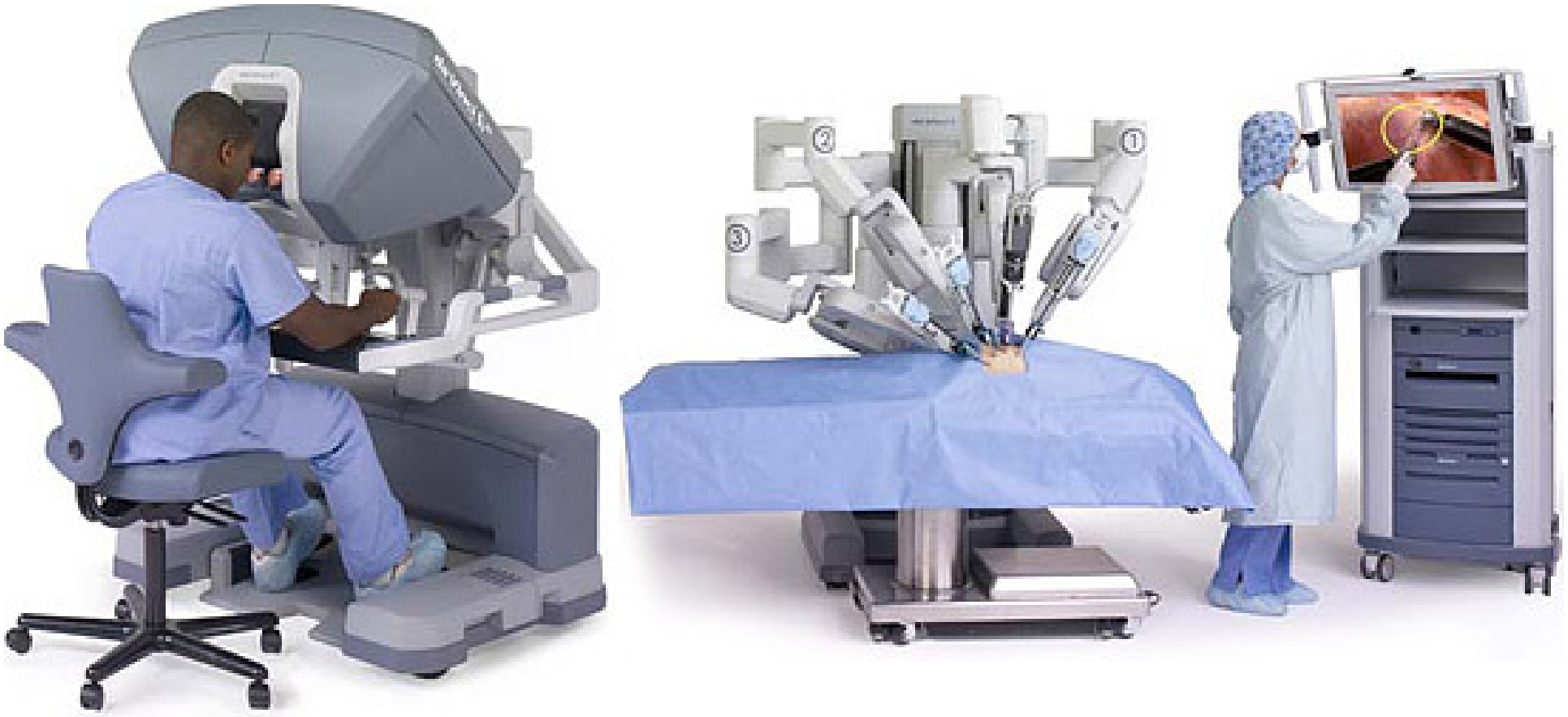
ZEUS Telesurgery Robotic system

http://www.websurg.com/robotics/history.php

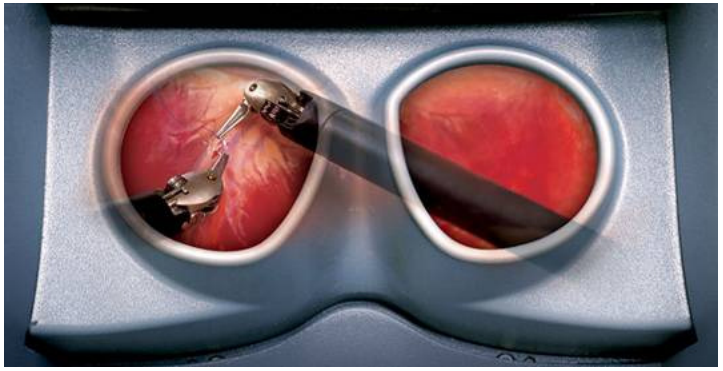
World's First Robotic Telesurgery

- **September 2001: Tele- chole (gall bladder removal)**
- **Surgeon in New York, Patient in France**
- **Round trip distance = 8,700 miles**
- **Round trip data time = 200 ms**
- **Collaborators: Prof Jacques Marescaux, New York & European Institute of Telesurgery, Strasbourg**
- **http://news.bbc.co.uk/2/hi/science/nature/1552211.stm**

da Vinci Surgical Robot



Essential Robotic Components



Stereo Vision

Stereo Mag Endoscope

7-DOF Instrument

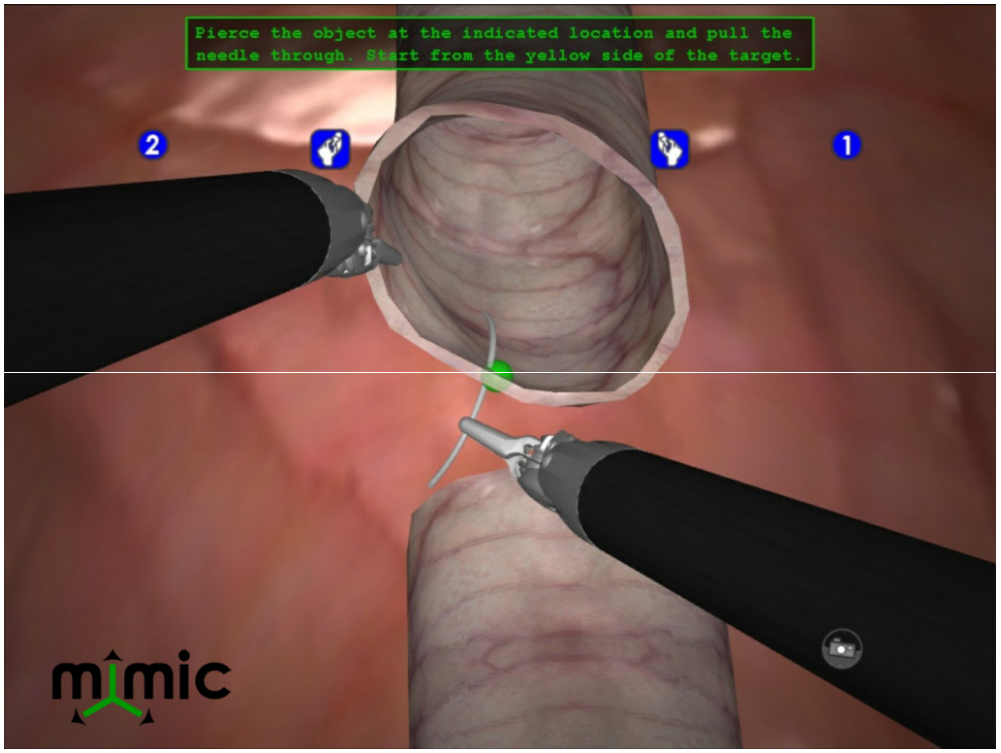
Ergonomic Station

Diverse, Small Instruments

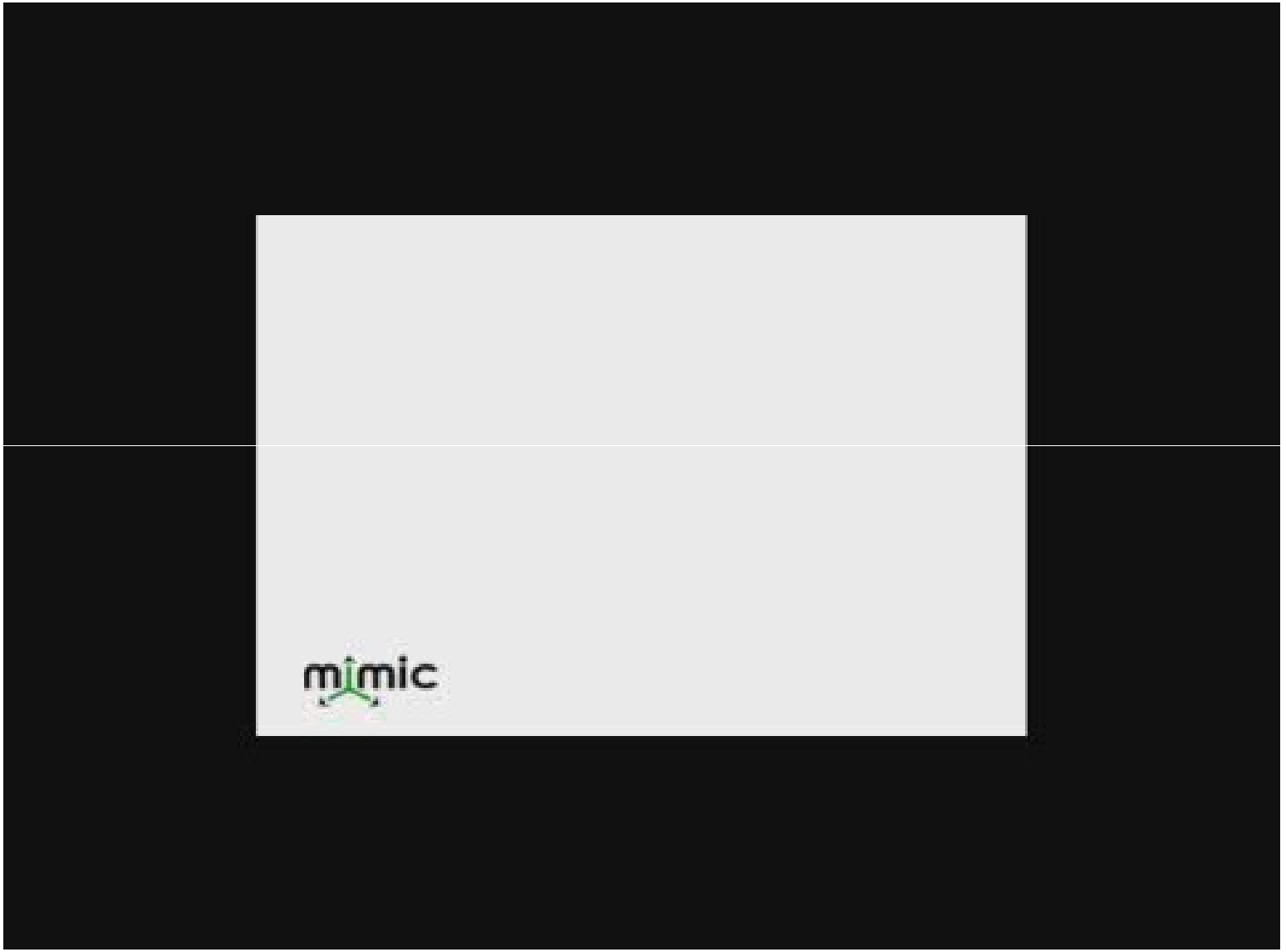
Fine Control

Intuitive Surgical's da Vinci Robot

Mimic dV-trainer for the da Vinci Robot



MIMIC dV Trainer



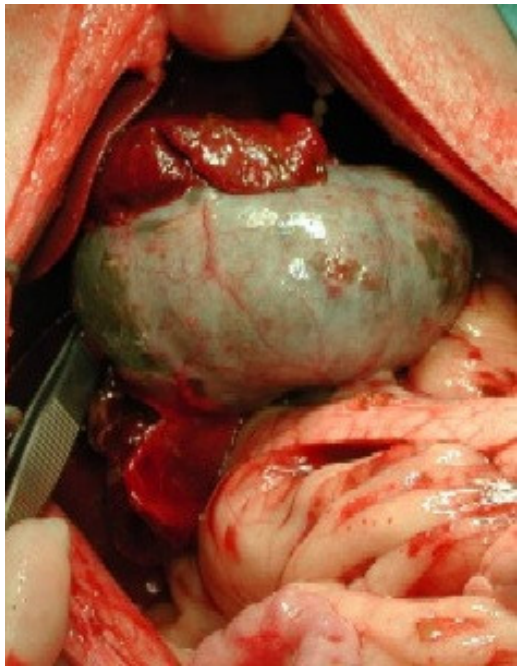
MIMIC Thread the Rings

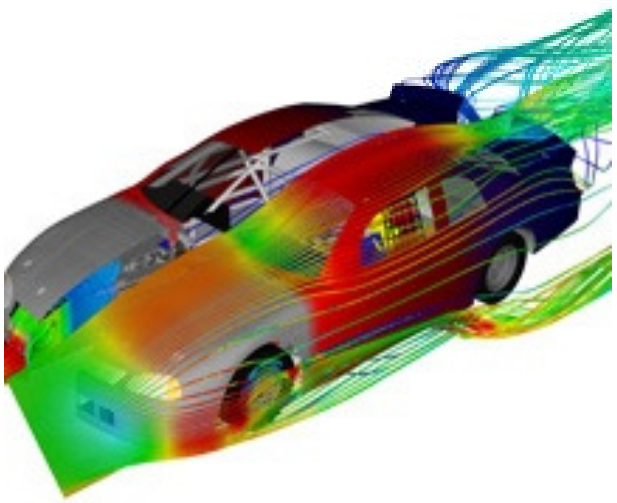
Modeling the World

Hard Objects
tanks, helos, ships

Human Body
living
tissue

Fluid Dynamics
water, air flow

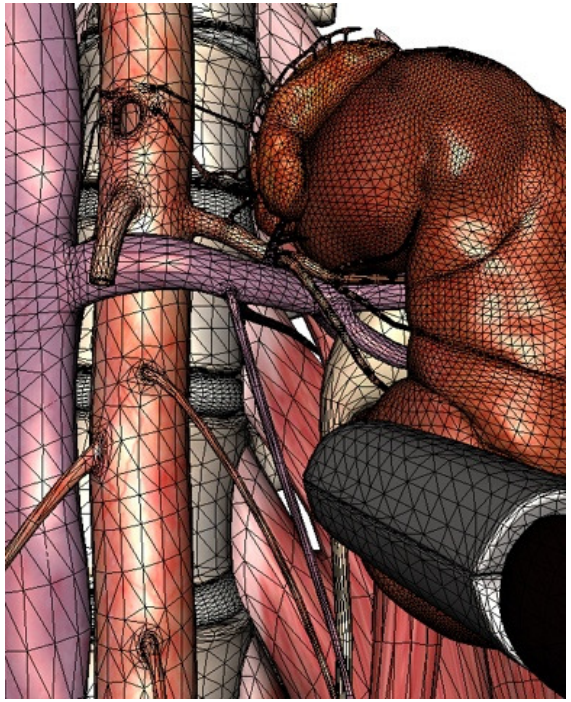




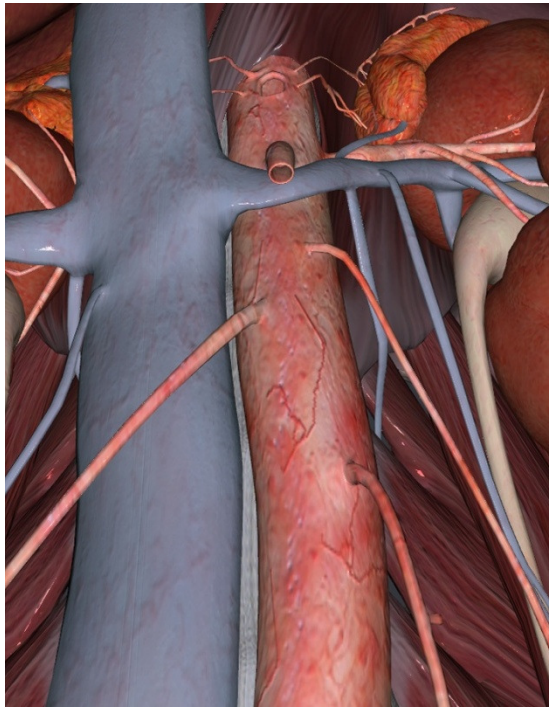
Hard Objects are Easy, Soft Objects are Hard

Unique Surgical Simulation Challenges

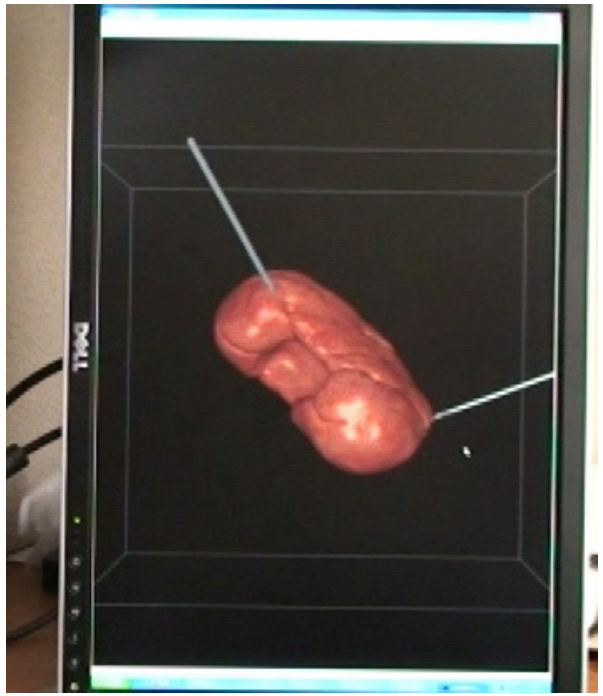
Geometry
- Complex
- Non-linear
- Non-uniform



Appearance
- Layered
- Translucent
- Dense



Dynamics
- Nerve movement
- Blood flow
- Elasticity



DoD Research Project

Robotic Curriculum

Consensus Conference:
- Define Robotic Surgery outcomes
- Develop Robotic Surgery curriculum
- Develop specific training tasks

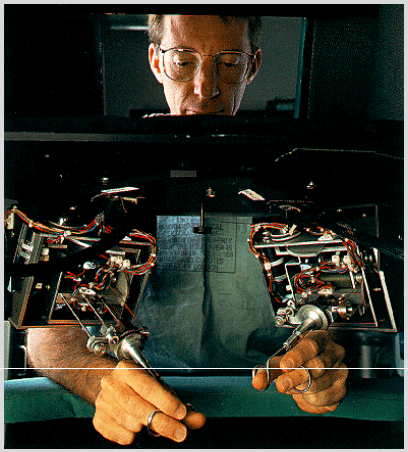
Curriculum Validation:
- Validate training tasks
- Identify testing measures
- Set passing criteria

Simulation

Military-use Validation:
- Identify military constraints
- Validate simulator for environment
- Define deployable package

Surgical Rehearsal:
- Develop test cases
- Conduct experiments
- Measure performance delta

Telesurgery



Communication Latency:
- Measure latency between cities
- Map surgical procedure to latency
- Redesign procedures for telesurgery
- Introduce instruments for safety

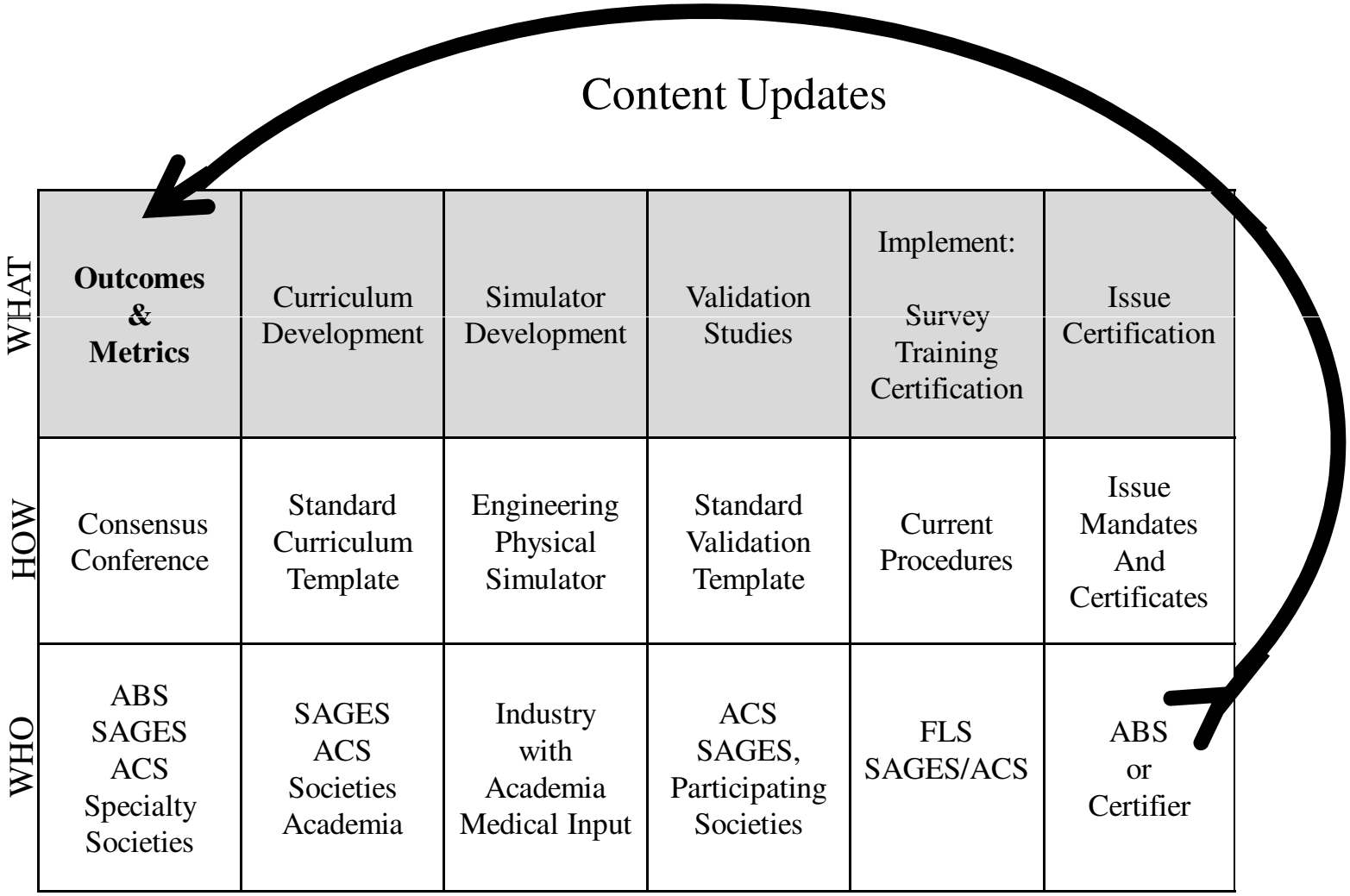
Automatic Surgery:
- Input simulated surgery data
- Execute data on da Vinci robot
- Measure accuracy of surgery

Nicholson Research Hypotheses

1. ***Telesurgery:*** **(a) For the foreseeable future, telesurgery will contend with telecommunication delays that affect the ability of the surgeon to execute a traditional surgical procedure in a telesurgery environment. We hypothesize that surgical movements can be modified to be effective and safe in a communication environment that contains predictable levels of delay. (b) Further, the data collected from a simulation event in Hypothesis 2 can be used as the basis for driving automatic robotic telesurgery with real equipment, which presents future possibilities for overcoming the communication latency problem.**
2. ***Simulation:*** **(a) We hypothesize that existing robotic surgery simulators can be used to retain and regain proficiency in robotic surgery. If validated, then deployed military surgeons can use these simulators while in a warzone to improve their ability to transition back into civilian practice. (b) Further, rehearsal of procedures with these simulators immediately before surgery will improve patient outcomes and will provide data which can be used to drive the automatic surgery experiments in Hypothesis 1.**
3. ***Robotic Curriculum:*** **We hypothesize that the methods used to establish the Fundamentals of Laparoscopic Surgery (FLS) curriculum in the previous decade can be applied to the robotic environment, creating a nationally accepted training curriculum for the Fundamentals of Robotic Surgery (FRS).**

Fundamentals of Robotic Surgery

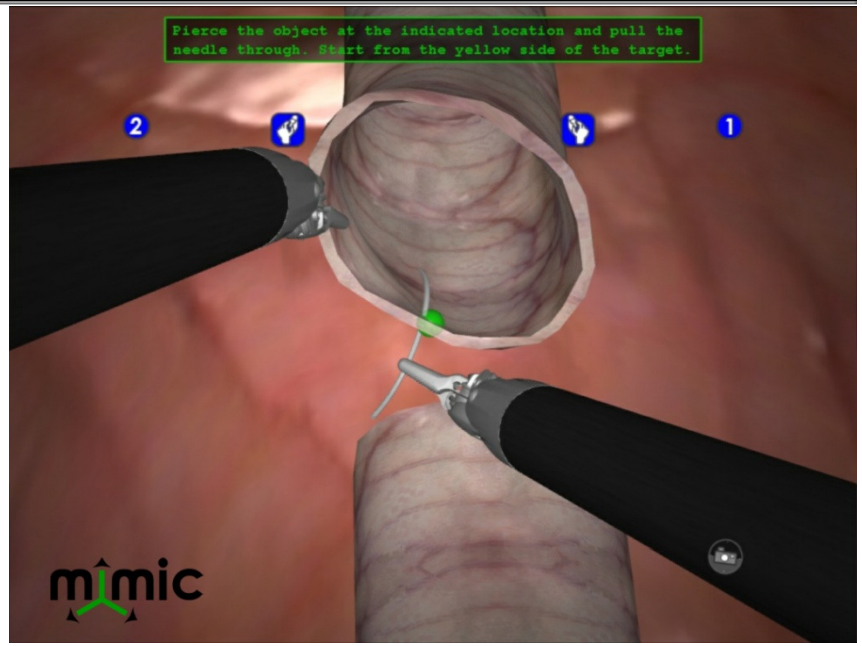
The Metrics Drive the Process

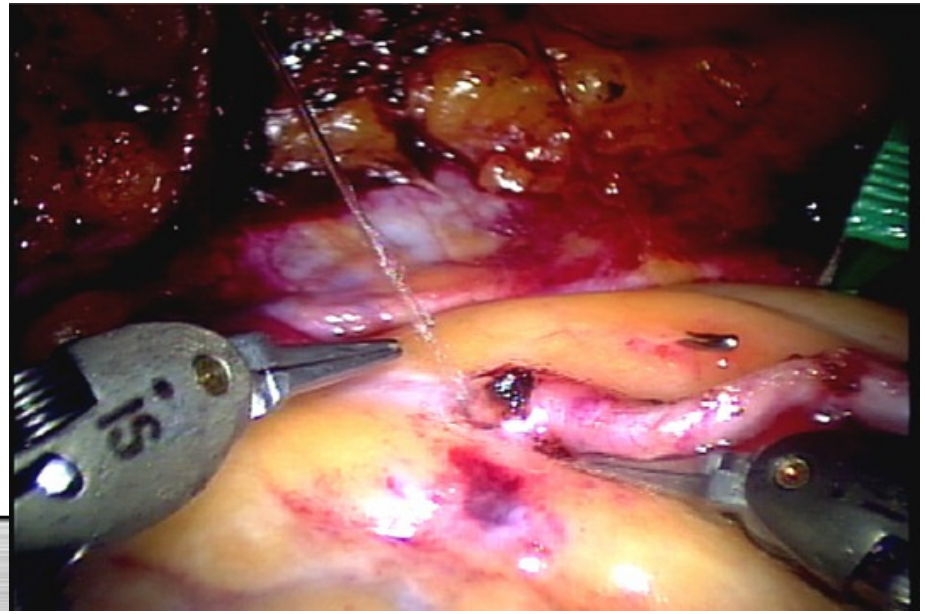


Military-use Validation

Robotic Surgery
Skills Retention

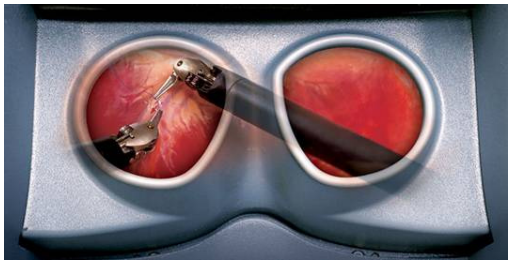
Surgical Rehearsal





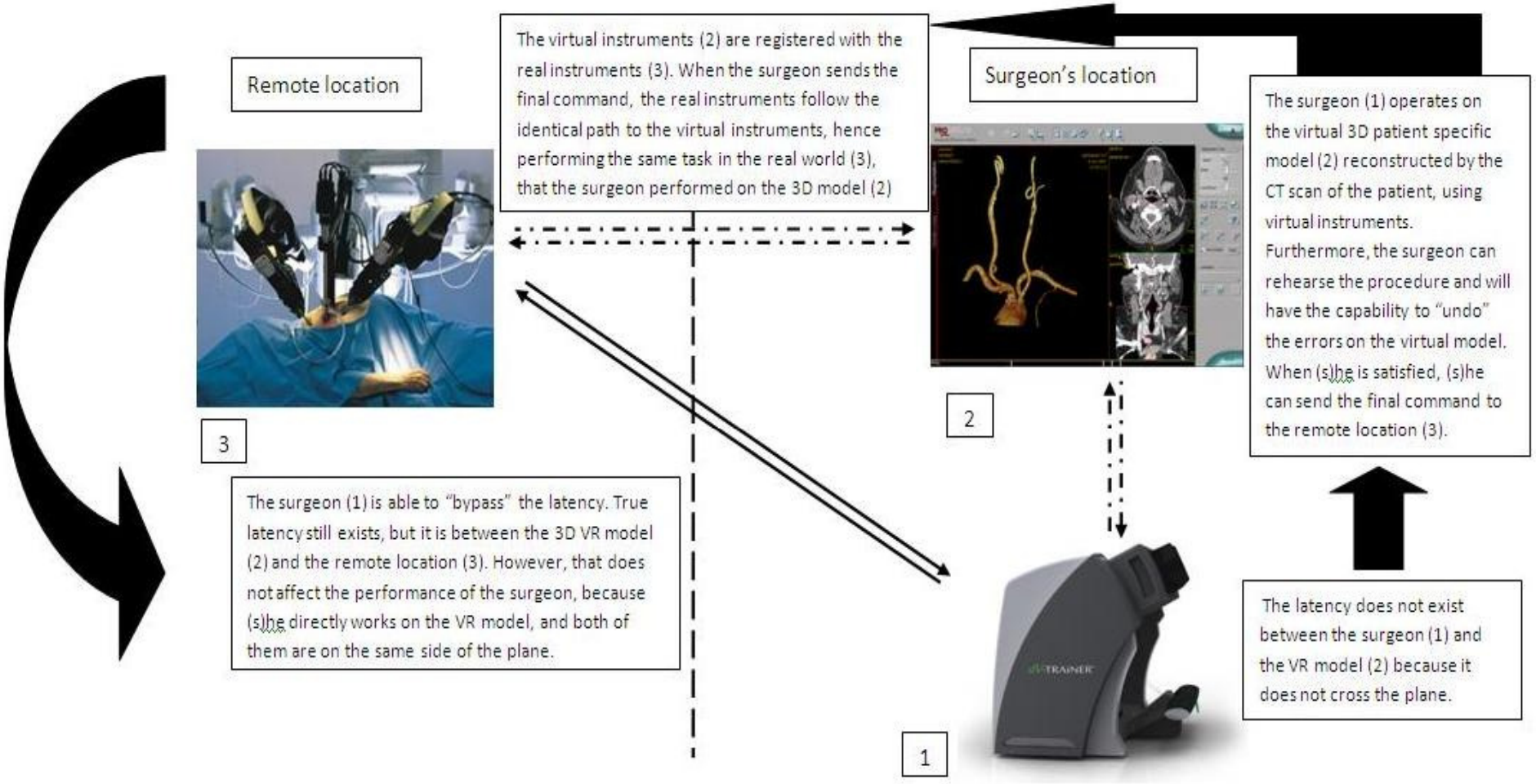
Communication Latency & Surgical Redesign

Internet



- **Change Pace**
- **Change Movement**
- **Add Instruments**
- **Eliminate Movement**

Automatic Surgery



Latency poses a significant problem while tele-manipulating the surgical instruments during RARTS.

Latency is experienced across this plane between the surgeon and the remote location.

Proposed pathway to "bypass" (not eliminate) the latency between the surgeon and the remote location.

Components of a Surgical Simulator (Harders, 2008)

Clinical Expertise

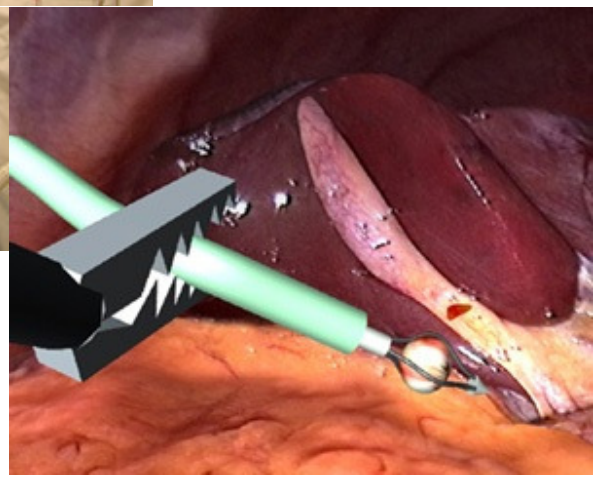
Model Generation

Vascular Structures

Bleeding Simulation

Tissue Parameters

Tissue Cutting



Organ Texturing

Tissue Deformation

Haptic Interface

Collision Detection

Fluid Simulation

Immersive OR

Summary

- **Surgical Robotics & Simulation are complimentary research**
- **Surgical Simulation presents unique problems from other Medical Simulation tools**
- **Modeling Soft Tissue is a unique new science**
- **Surgical Simulation architecture is evolving**
- **Simulation as a significant part of the surgical education curriculum is an emerging field**
  - **Not currently accepted**
  - **Only recently technically viable**
  - **Big culture shift required**
  - **Government policies will be a significant force**

Reference Books

- Harders, M. (2008). *Surgical Scene Generation for Virtual Reality-Based Training in Medicine*. Springer Publishing.
- Kyle, R & Murray, W. (2008). *Clinical Simulation: Operations, Engineering and Management*. Academic Press.
- Riley, R. (2008). *Manual of Simulation in Healthcare*. Oxford Press.
- Satava, R. et al. (2007). *Emerging Technologies in Surgery*. Springer Publishing.
- Smith, R. (2009). *Game Technology in Medical Education*. Modelbenders Press.

Presentation Available

Slides at:

http://www.modelbenders.com/papers

Videos at:

Da Vinci Overview

http://www.youtube.com/watch?v=ozyv3x1ivts

MIMIC Simulator

http://www.mimic.ws/resources

Ross Simulator

http://www.youtube.com/watch?v=bICtjMCeXmQ