Simulation and Game Technology in Medical Education

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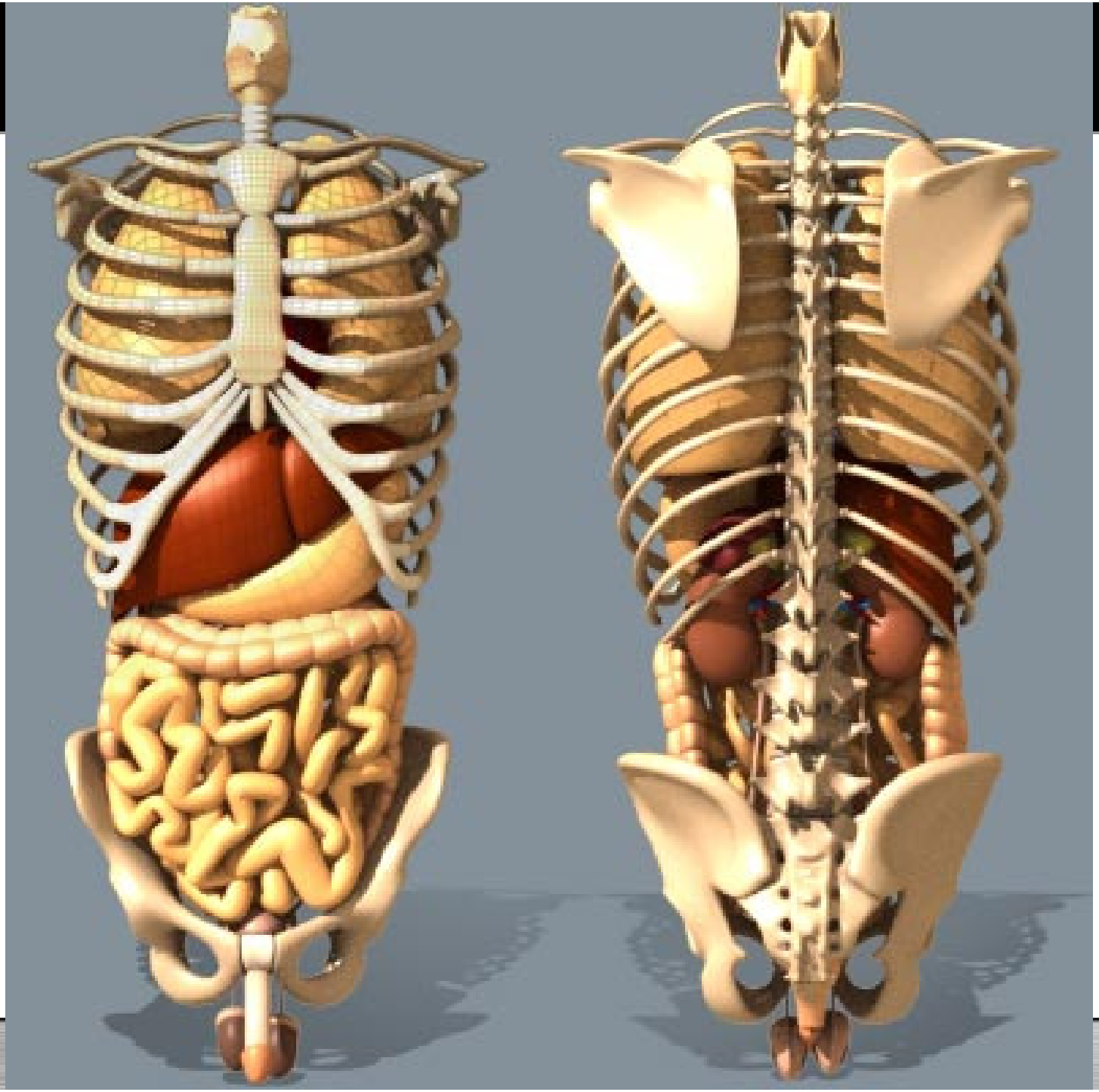
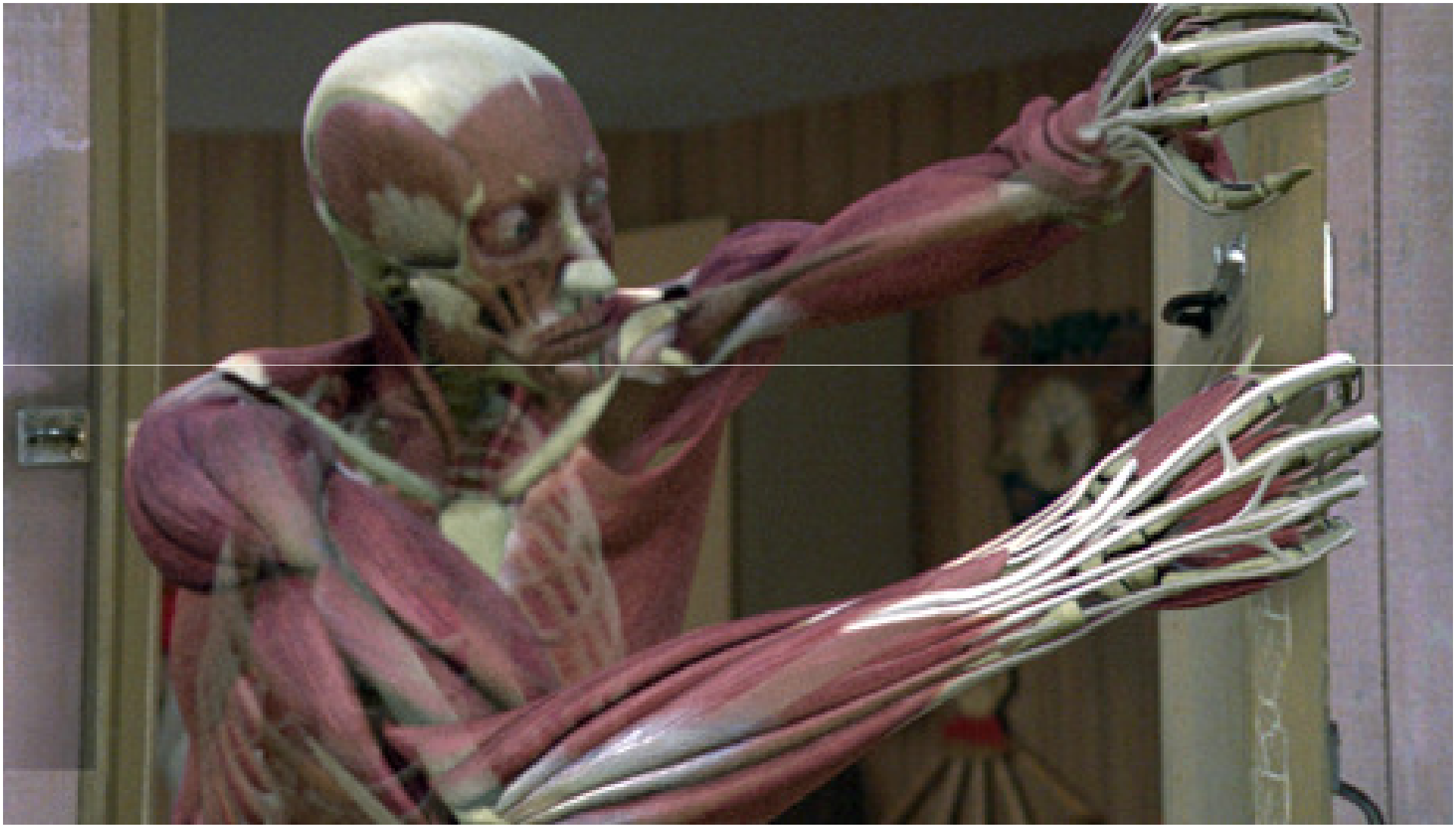
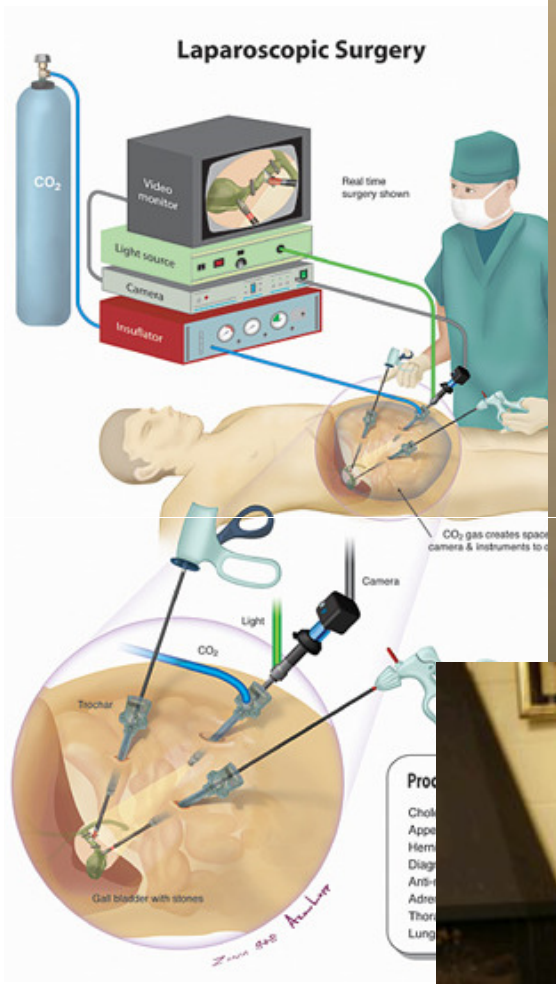
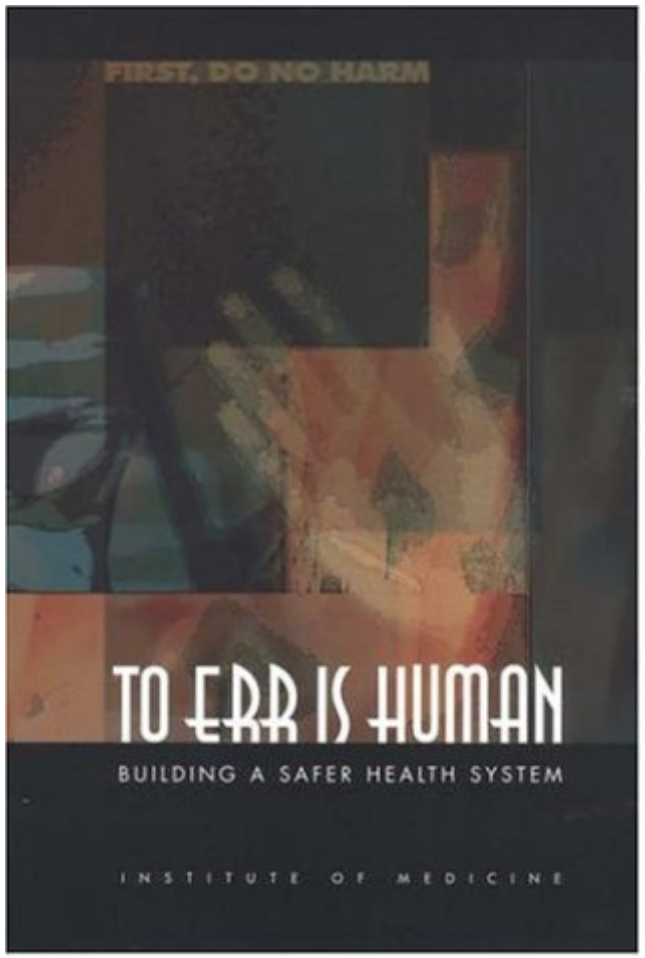


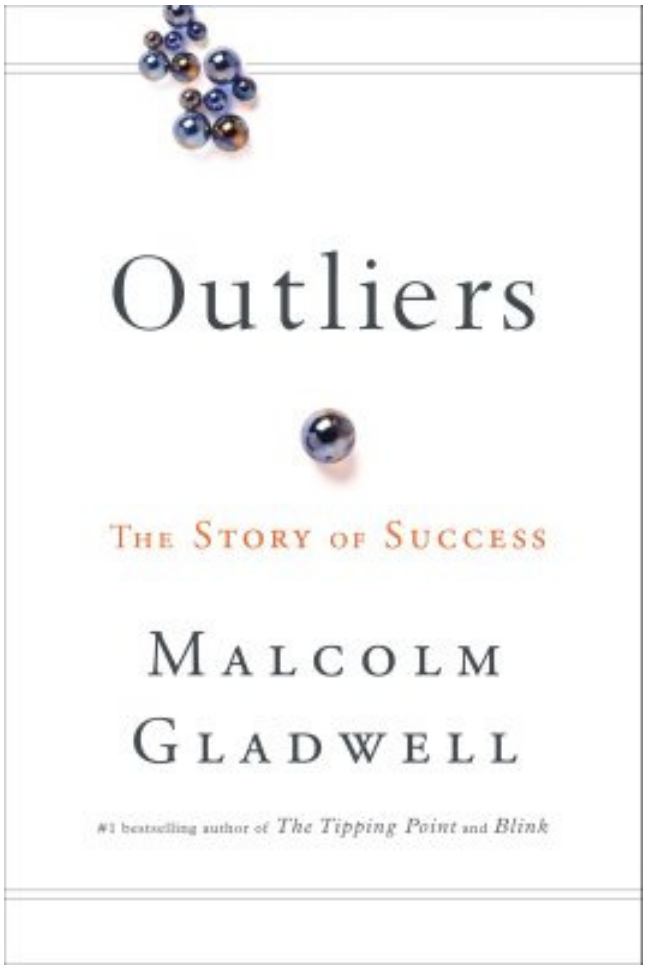


The Surgical Pilot – a common analogy



Creating Experts & Eliminating Errors





10,000 hours to become an expert - Gladwell

“There is no excuse for the surgeon to learn on the patient.” – William Mayo, 1927

Pilots do not learn on passengers.

Classical Elements (Empedocles, 450BC)

Classic Military Simulation Elements

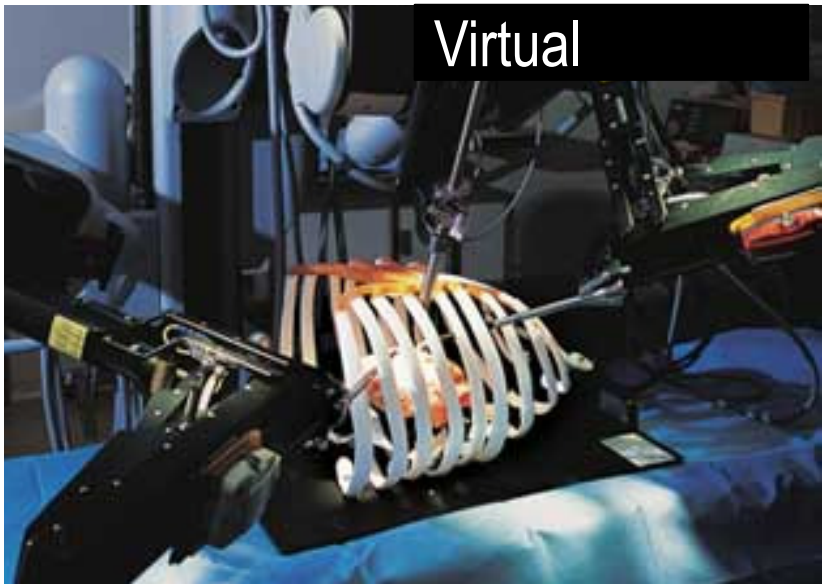
Live

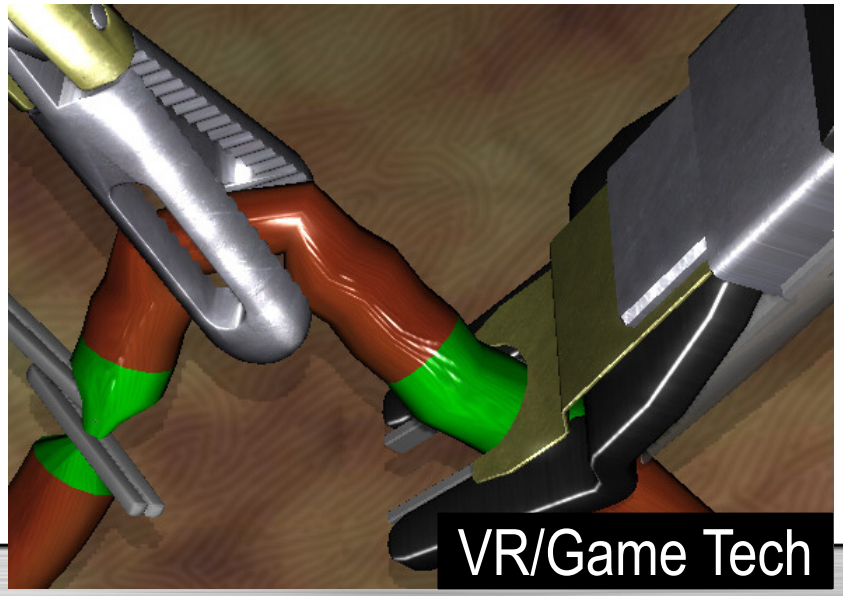
Virtual

Constructive

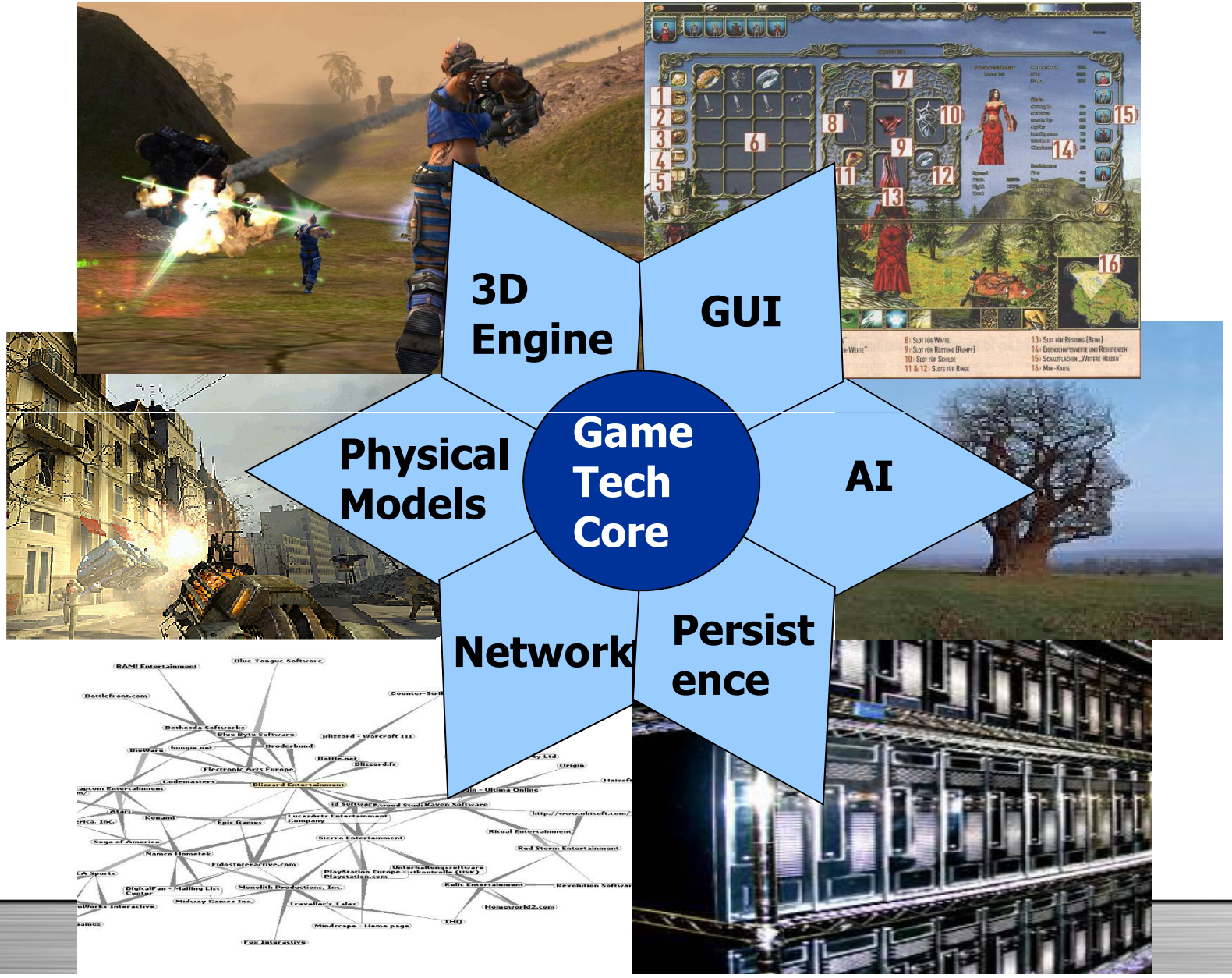
Games

Civilian Surgical Simulation Elements





Game Technologies



Training Technology Options

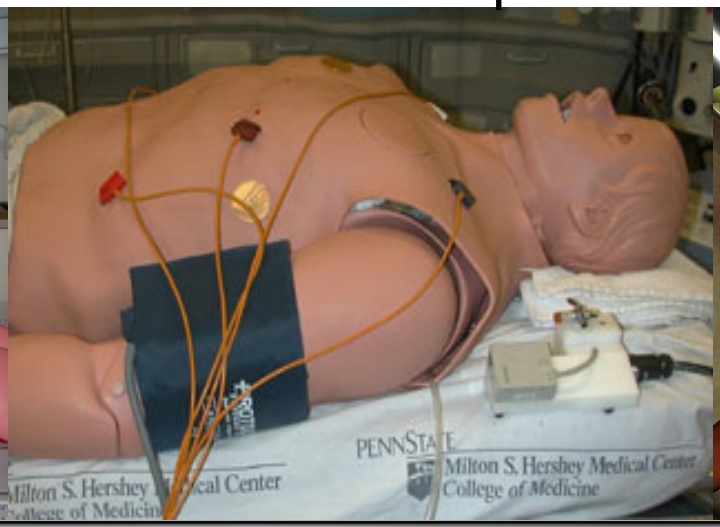
Human

Animal

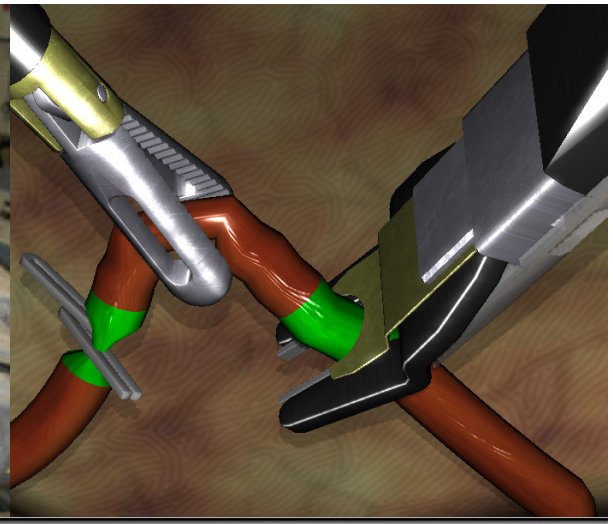
Box Trainer

Part Task

Mannequin

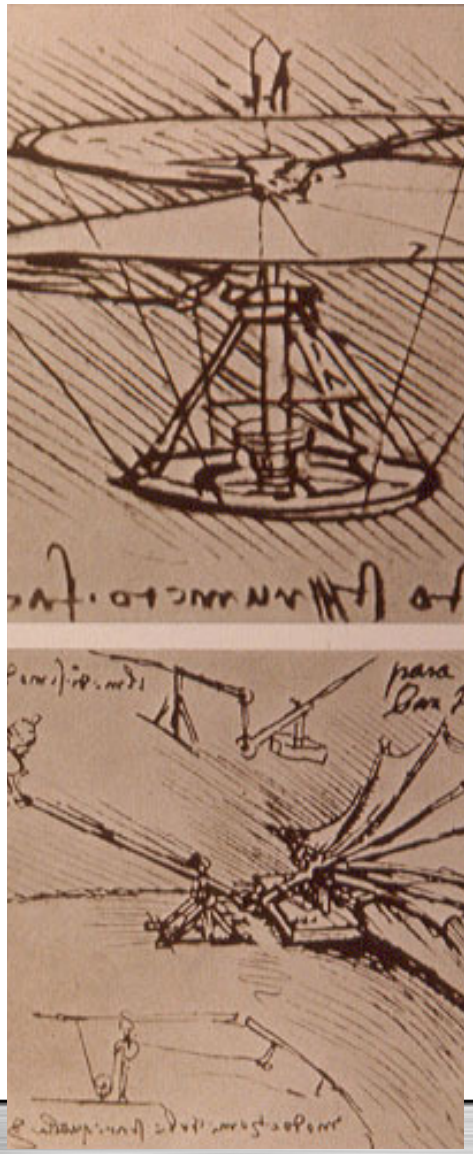


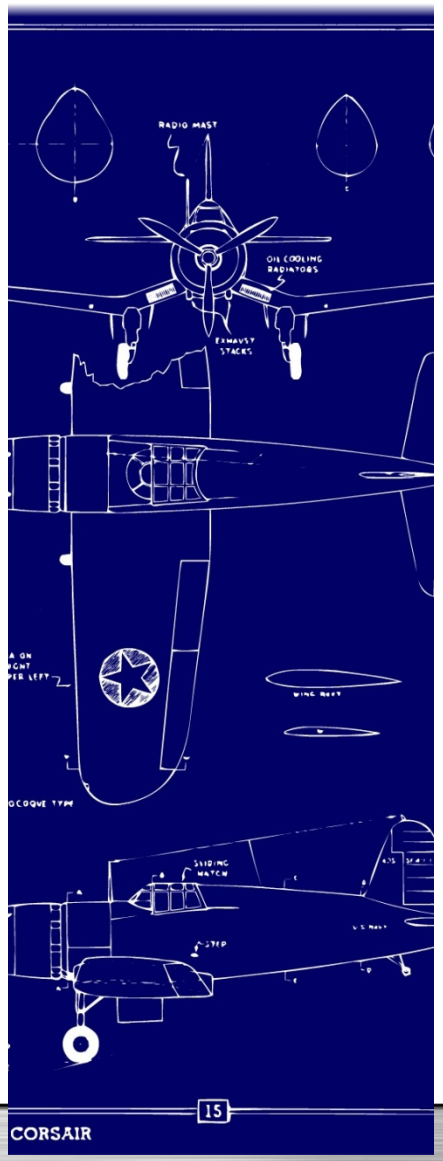
VR/Game Tech



Human	Animal	Box Trainer	Mannequin	Simulation	VR/Game
Learn on humans: Living patients, the newly dead, and cadavers	**Learn on animals:** Living and newly dead pigs, cats, and others	**Learn on organs in a box:** Human-shaped box contains organs, tissue, or test devices	**Learn on a physical replica:** A full-body device with synthetic skin, organs, and fluids	**Learn on an animated machine:** Includes computer, hydraulics, pneumatics, and electrical responses	**Learn on computer images:** Mathematical models, visual images, sounds, and some tactile feedback
Advantage Exact Replica, Existing OR	**Advantage** Similarities, Availability	**Advantage** Availability, Convenience, Human Shape	**Advantage** Human Shape, Logistics	**Advantage** Rich Experience, Multi-Function, Programmable	**Advantage** Rich Experience, Flexibility, Low Cost
Disadvantage Scarcity, Single Use, Ethical Issues	**Disadvantage** Anatomy, Single Use, Social Mores	**Disadvantage** Not Alive, Single Use, Animal Organs	**Disadvantage** Static, Lacks Realism	**Disadvantage** High Cost, Complexity	**Disadvantage** Screen-barrier, Non-tactile
Examples Cadavers Live Patients	**Examples** Porcine Labs	**Examples** MIC-Trainer	**Examples** CPR Annie	**Examples** Sim One HPS	**Examples** MIST-VR dV-Trainer

Communication Tools are Generational





Motivation

Medical Education – Explosion of Information

- Medical procedures are becoming more numerous and more complex – medical knowledge has “hypertrophied” (Cooke, 2006)

- Training residents to a common level of knowledge and competence is already impossible (Satava, 2008)

"The Perfect Storm" (Murphy, 2007)

- Risk to patient health. (McDougall, 2007)
- Ethics of practicing on patients. (Satava, 2004; Murphy, 2007)
- Cost is a barrier to training. (Bridges, 1999)
- Insurance coverage of educational actions. (Satava, 2004)
- Working hour limits. (Satava, 2004)
- Availability of training opportunities. (Birden, 2007; Davis, 1999)
- Access to training. (Dunkin, 2007; Spitzer, 1997)
- Complexity of modern surgery. (McDougall, 2007)
- Volume of unique procedures. (Reznick & MacRae, 2006)
- Proficiency-based Medicine. (Murray, 2005)
- Quality of technology. (Murphy, 2007)
- Expectations around computer technologies. (Murphy, 2007)
- Acceptance of technology. (Ziv, 2003)
- Learning from Mistakes. (Ziv, 2005)

Objectives for Simulation/GameTech

- **Objective 1: Lower Cost**
- **Objective 2: Better Access to Symptoms/Cases**
- **Objective 3: Reduced Training Time**
- **Objective 4: Reduced Errors**

Similar Motivations for Military, Industrial, and Medical Training

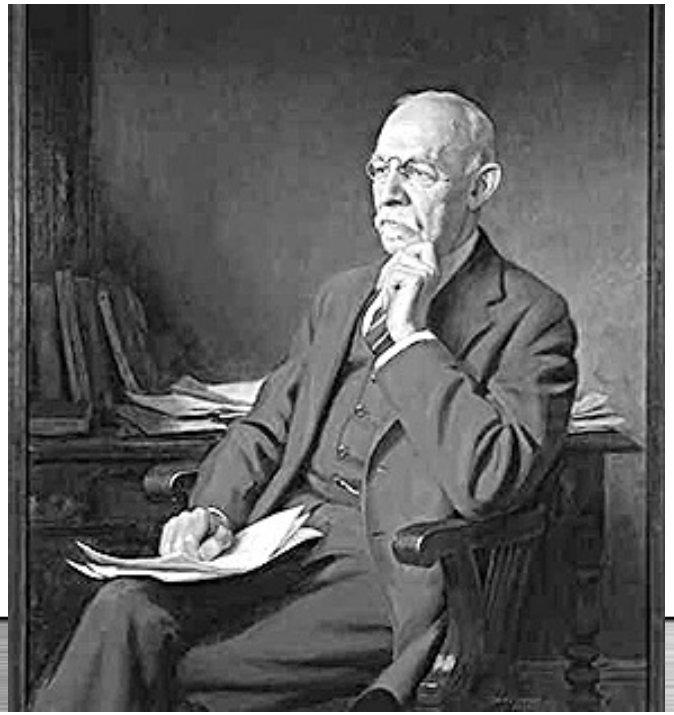
Objective 1: Lower Cost

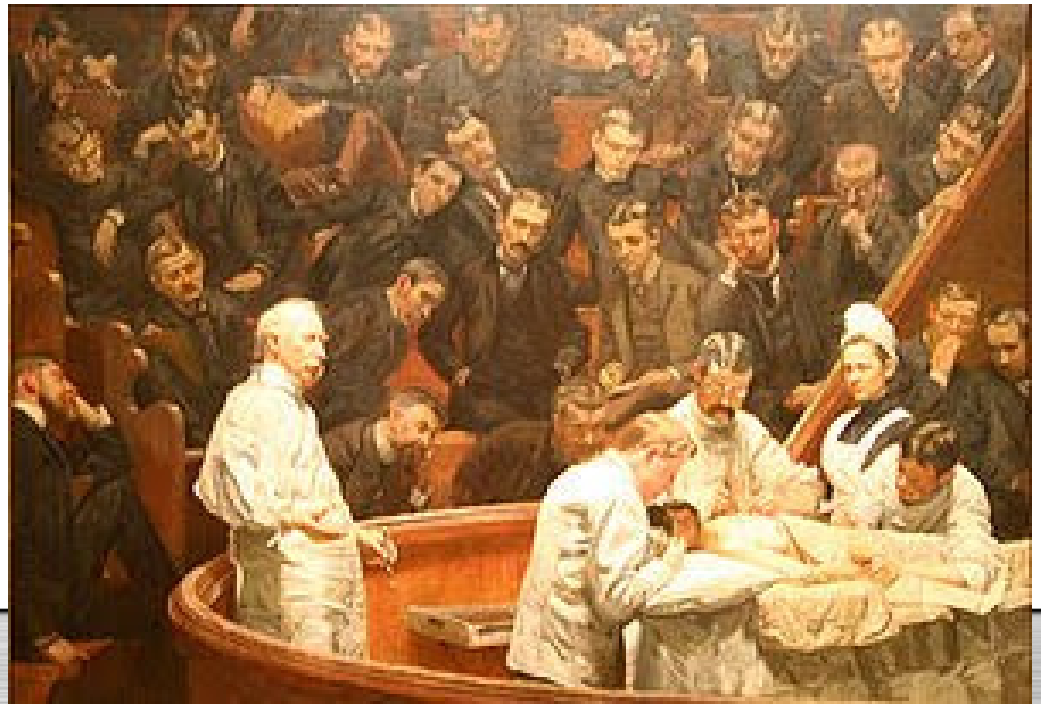
- Surgery as a teaching event consumes resources that could generate additional revenue. (Bridges & Diamond 1999)
  - Accumulates to 186 hours over a 4 year residency
  - Estimate operating room costs at $257.40 per hour.
  - Adds $47,970 to the cost of a medical education.

- Alt: Adds $186,363 to $279,545 during four year residency
  - US operating room $1,500 per hour (Frost & Sullivan, 2004)
  - Swedish operating room $1,000 per hour (Hyltander, 2003)

Objective 2: Better Access

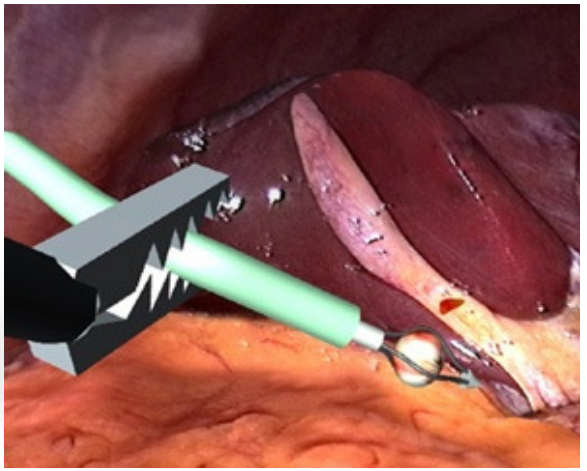
- "The traditional Halstedian apprenticeship model of 'see one, do one, teach one' is no longer adequate to train surgeons
- Good laparoscopic skills cannot be developed by merely watching an expert.
- Laparoscopic proficiency is only realized after sufficient practice in the minimally invasive environment." (Pearson et al, 2002)
- Learning begins with "do one" (Jordan et al, 2001; Gallagher et al, 2001b; Madan & Frantzides, 2007).





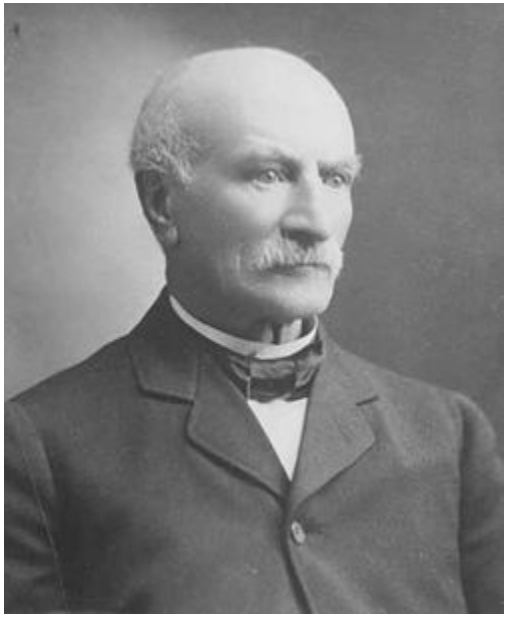
Objective 3: Reduced Time

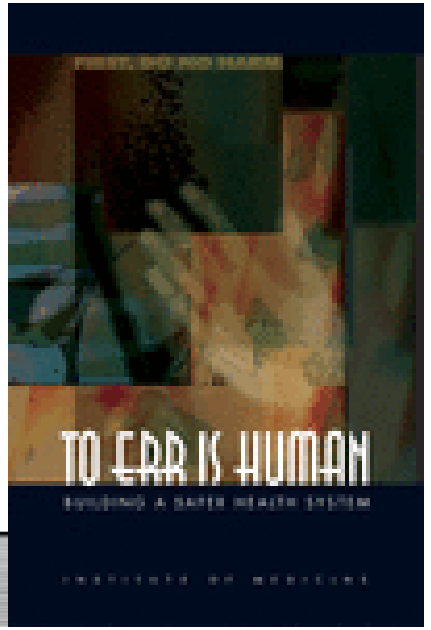
- Both MIST-VR and GI-Mentor differentiate experienced from inexperienced users based on their performance scores with the simulator (Adamsen et al, 2005)
- MIST-VR simulator could determine which students will never achieve proficiency and should be dropped from a training program (Gallagher et al, 2004)
- Students trained in VR are 29% faster at performing laparoscopic surgeries and make up to five times fewer mistakes (Enochsson et al, 2004; and Seymour, 2002)
- Non-VR trained students are nine times more likely to fail to make progress in their performance than those who use VR in their training (Seymour, 2002)



Objective 4: Reduced Errors

- "There is no excuse for the surgeon to learn on the patient." (William J. Mayo, 1927).
- Medical error is responsible for between 44,000 and 98,000 deaths per year (IOM, 1999).
- Laparoscopic surgery has an error rate that is three times higher than that of open surgery. Error rate has not been decreasing over an eight year period as surgeons become more experienced (Huang et al, 2005).
- In laparoscopy, observation does little to convey the skills that must be mastered. Only actual practice has been effective at this (Jordan et al, 2001; Gallagher et al, 2001b; Madan & Frantzides, 2007).
- VR systems are one tool that can improve the performance of surgeons because they become familiar with the appearance of organs and tissue on a two dimensional computer monitor (Huang et al, 2005).



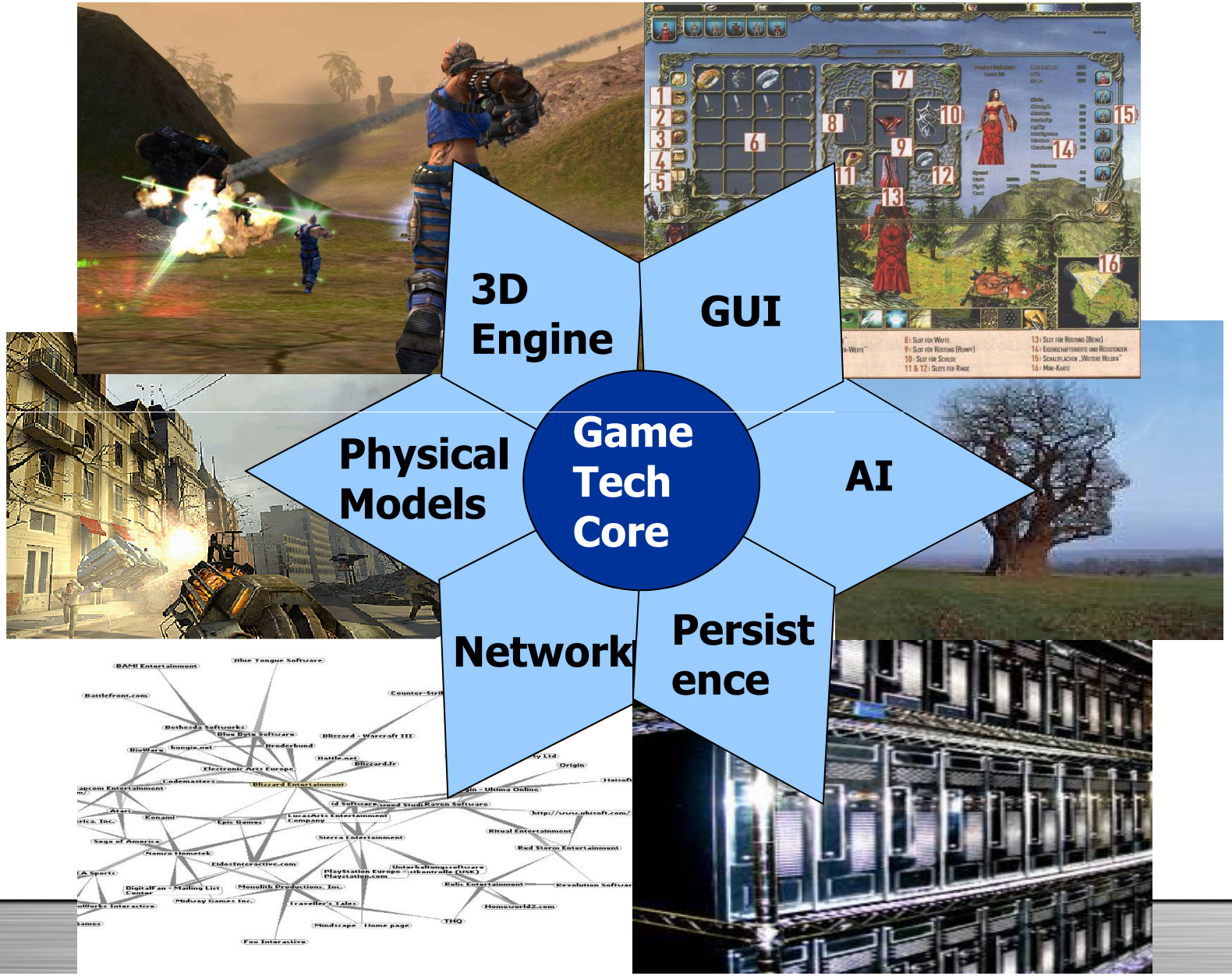


Misleading Assumptions on Traditional Methods

- Assumption 1: Didactic Education is Effective
  - Though surgeons or residents may learn new information during educational lectures, they do not incorporate it into their practice. It has no impact on their actions in delivering medicine. (Davis et al 1995 & 1999; Weller et al 2005)
- Assumption 2: Sufficient Access to Faculty and Patients is Possible
  - Availability of faculty is a major limitation in medical education (Dunkin et al, 2007; Satava, 2008)
  - Many studies assume adequate access a priori (Gerson & Van Dam, 2003)
- Assumption 3: Practicing on Live Patients is Acceptable
  - Medical schools, faculty, and residents are finding new restrictions on the type and amount of training that can be conducted with a live patient (Murphy et al, 2007; Murray et al, 2005; Satava, 2004a; Ziv et al, 2005).

VR & Game Tech

Game Technologies

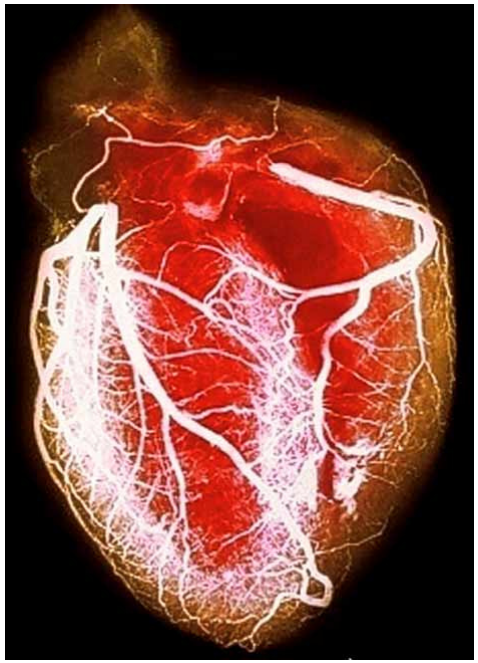


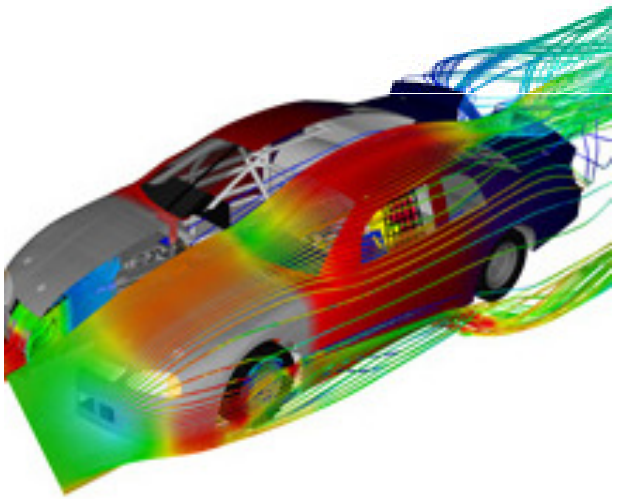
Modeling the World

Hard Objects
tanks, helos, ships

Human Body
living
tissue

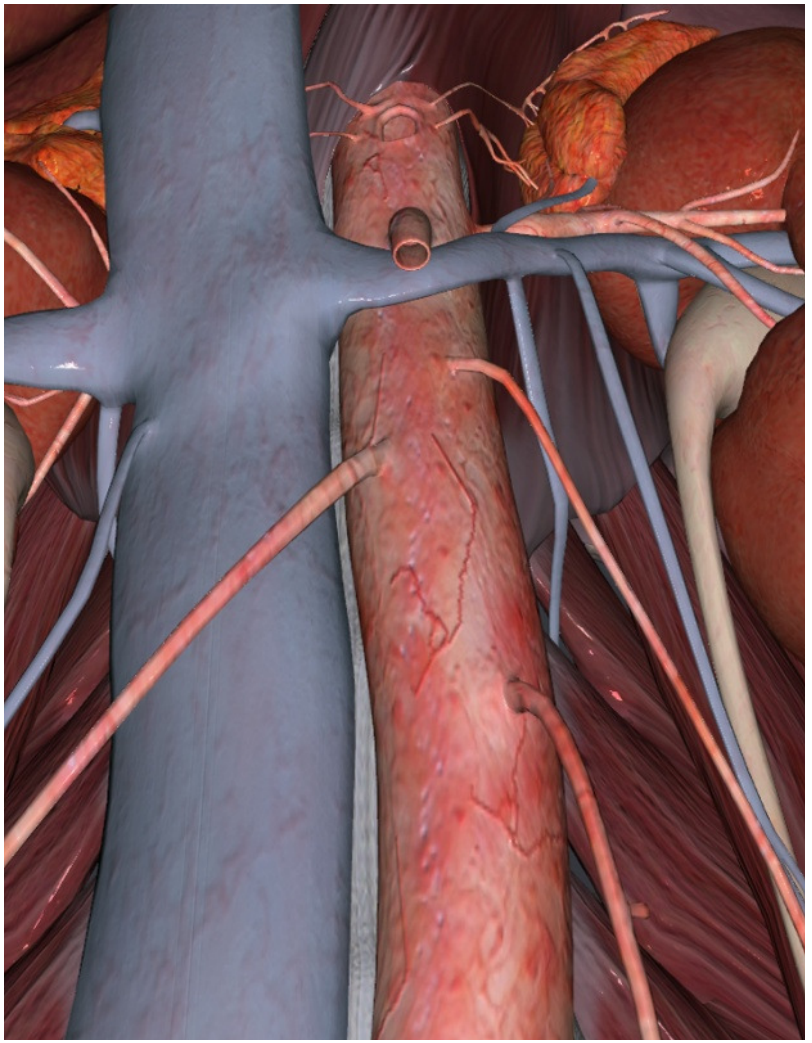
Fluid Dynamics
water, air flow





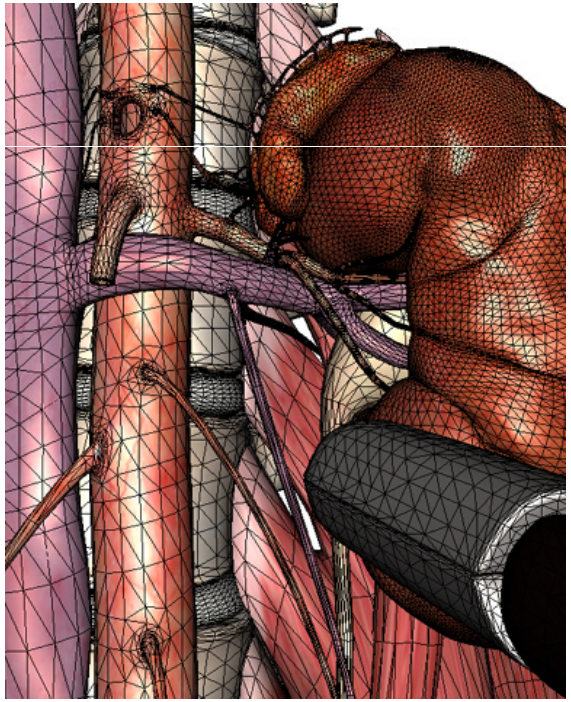
Hard Objects are Easy, Soft Objects are Hard

Focusing Outside vs Inside

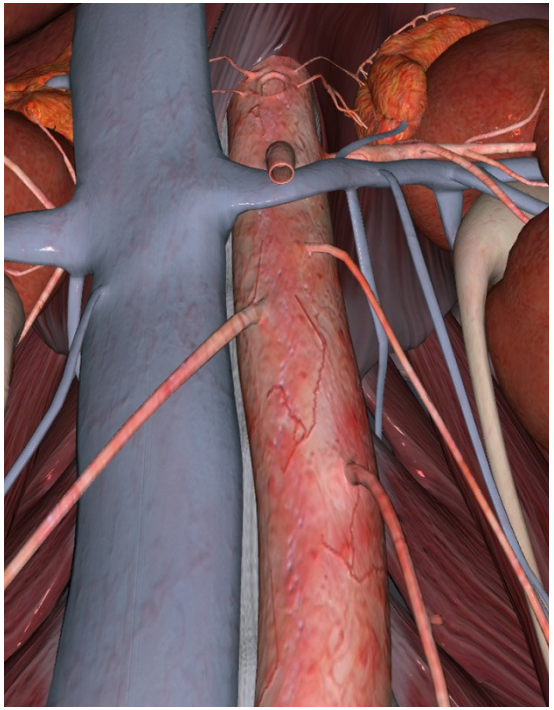


Surgical Scene Generation

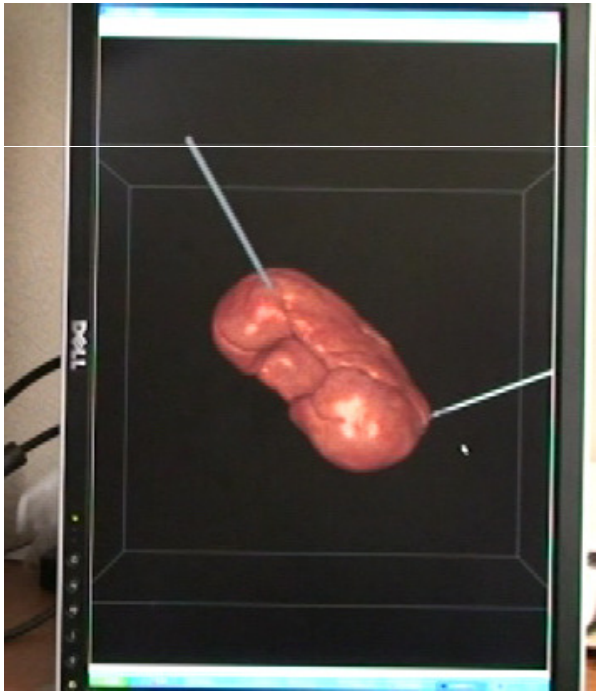
Geometry
- Complex
- Non-linear
- Non-uniform



Appearance
- Layered
- Translucent
- Dense



Dynamics
- Elasticity
- Nerve movement
- Blood flow



Modeling Approaches

- **None:** Omit Feature and Behavior from the Simulation
- **Geometry:** Size and placement of organ
- **Stochastic:** Probability of Injury, Mean Time Between Failure
- **Logical:** Tissue Properties, Flow Rates
- **Physics:** Force, Mass, Friction, Cellular behavior
- **Artificial Intelligence:** Human Decision & Perception

Heart Surgery: Simulation + Animation

Second Life ED – a physician & staff trainer

Real Data

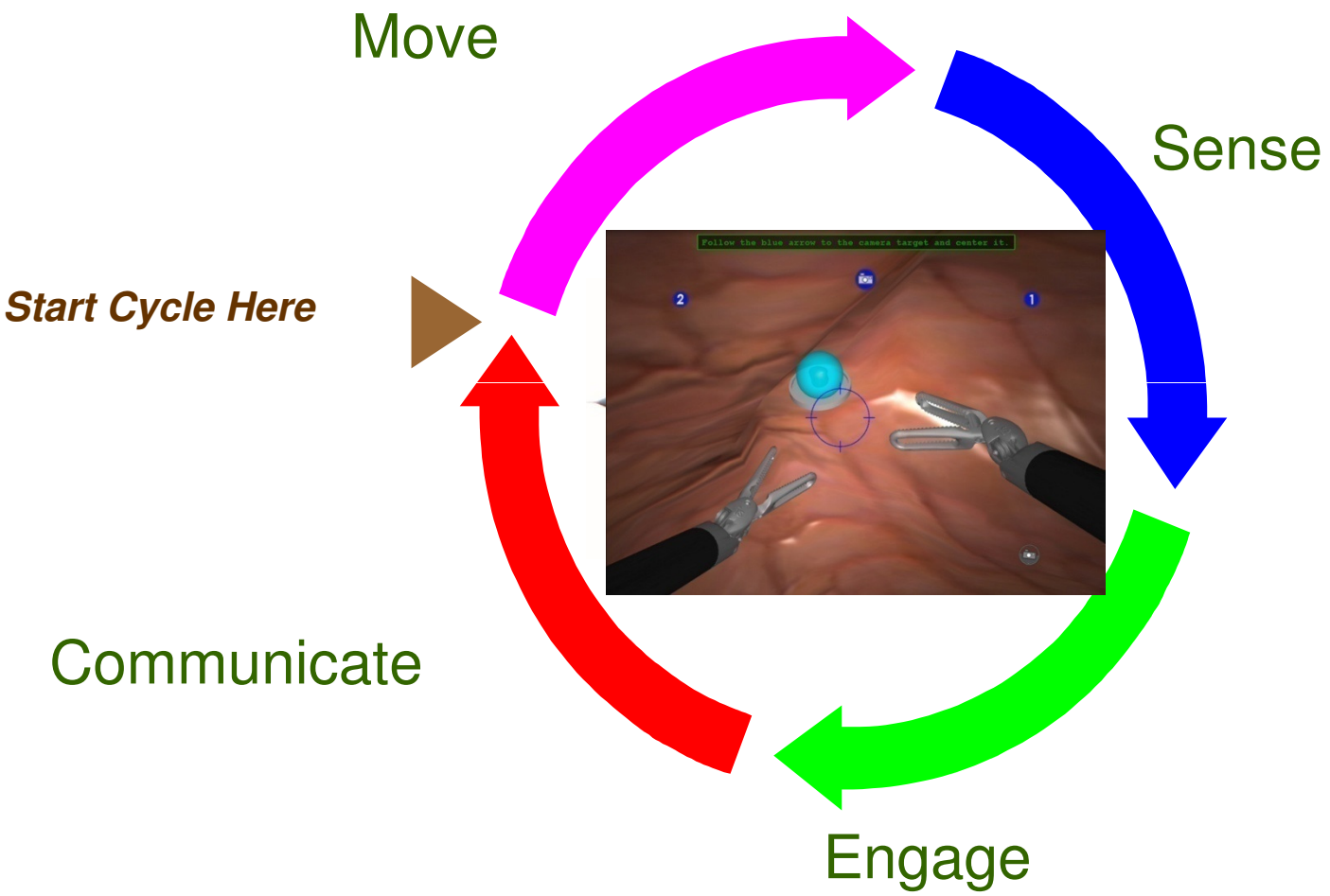
Decision Making

Real Time

Collaborate

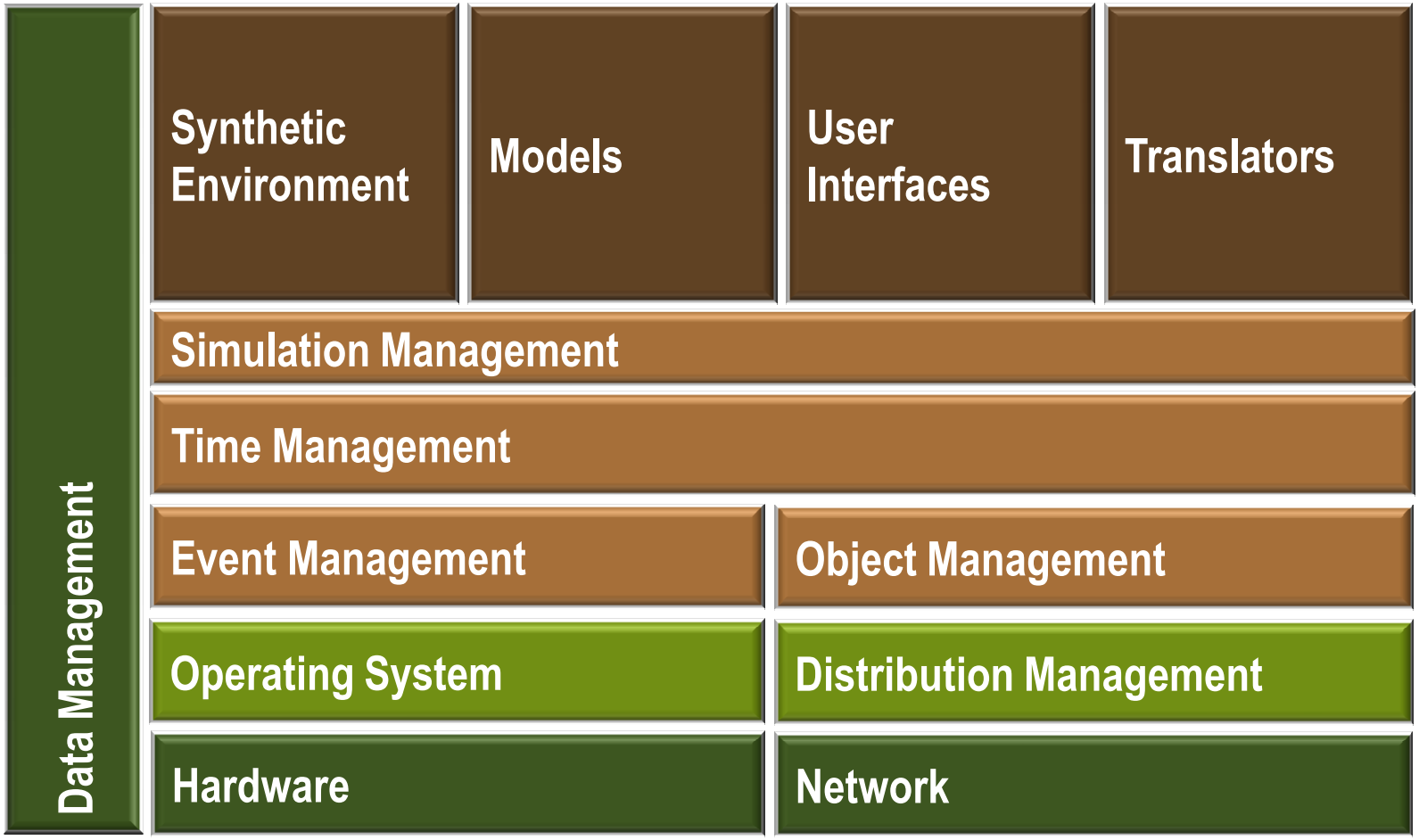
Group Practice

Physical Modeling Cycle



From *Military Simulation and Serious Games*, Roger Smith

Simulation Software Design Pattern



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Components of a Surgical Simulator (Harders, 2008)

3D Model Generation

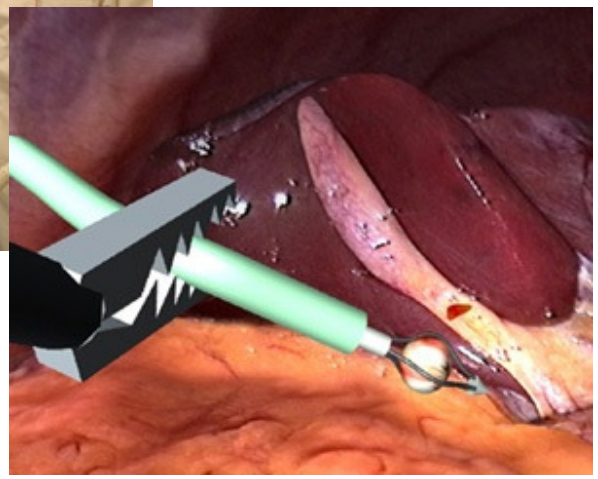
Fluid Simulation

Vascular Structures

Bleeding Simulation

Tissue Parameters

Tissue Cutting



Organ Texturing

Tissue Deformation

Haptic Interface

Collision Detection

Clinical Expertise

Immersive OR

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