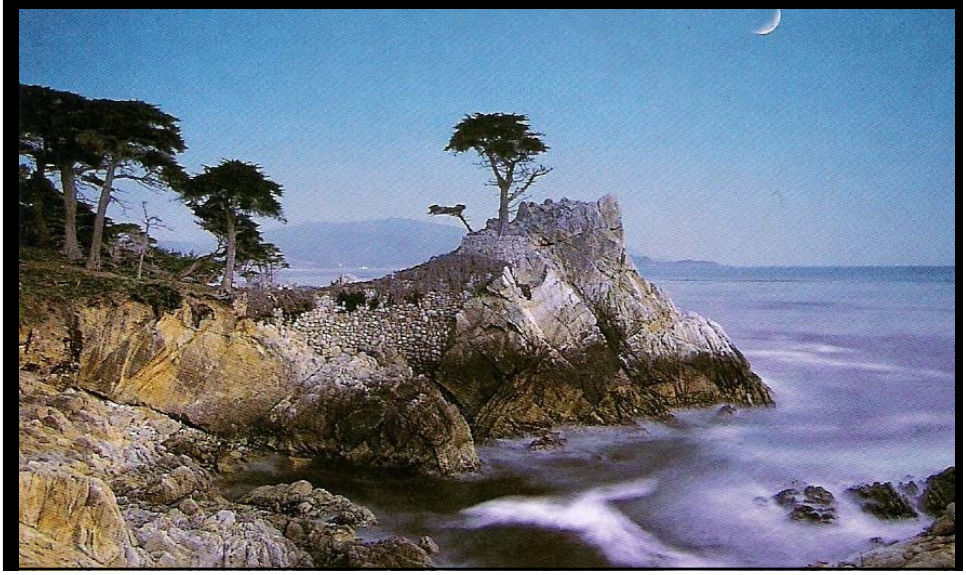
# FUTURE

## Innovation and Advanced Technology for the Future of Healthcare

Richard M. Satava, MD FACS
**Professor of Surgery**
University of Washington

http://depts.washington.edu/biointel

## Greetings from Monterey California

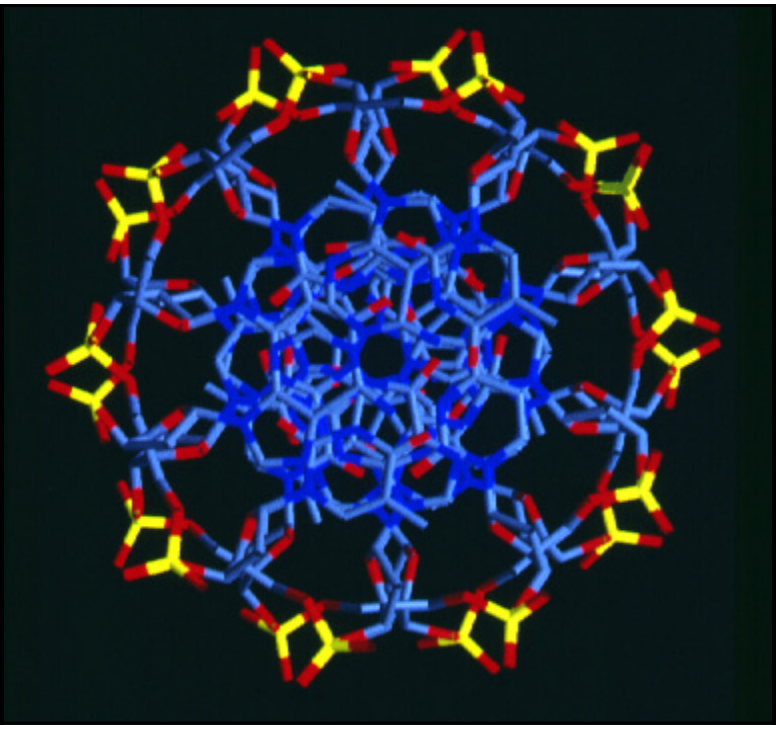


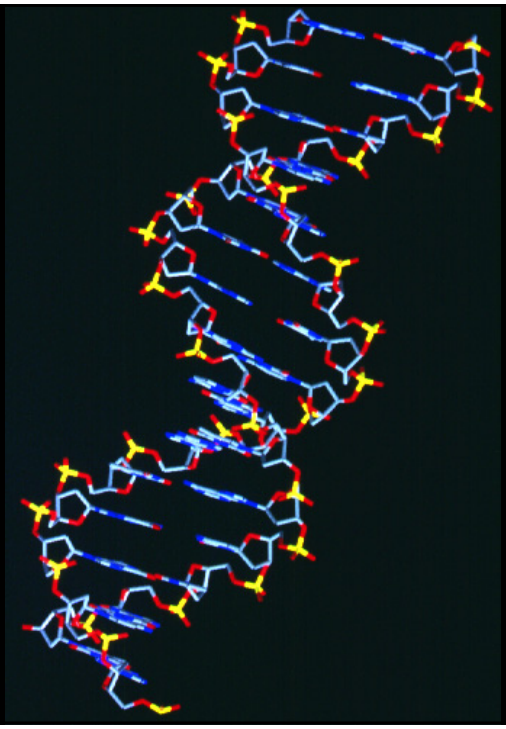
# Presenter Financial Disclosure Slide

**Richard M. Satava, MD FACS**

| | |
|---|---|
| Financial Support: | None (… but still hoping) |
| Consulting: | Karl Storz |
| ISIS Support | Stryker<br>SimuLab<br>US Surgical |
| Investment | InTouch Technologies, Inc |

* There will be no discussion of products from these companies





# Disruptive Visions

"The Future is not what it used to be"

....Yogi Berra

EXPECTATIONS

## What does your patient want?

Arrives in the office and expects:

- Infinite amount of time
- Instant diagnosis
- Immediate treatment
- Absolutely no pain
- Leaves cured!

## Physician as Super Hero

## Fundamental Concept

New technologies that are emerging from Information Age discoveries are driving our basic approach in all areas of healthcare education

…EXAMPLES

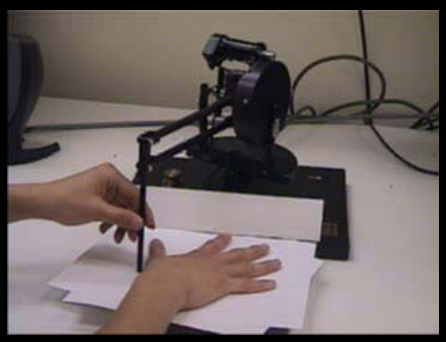
# Current Visions

*"The Future is here ...*

*. . . it's the Information Age"*

# Why Robots?

Movie: Alien

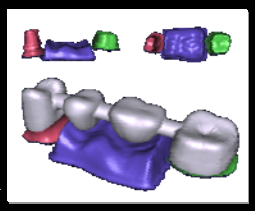


The Touch Lab, MIT

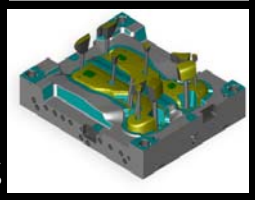
# The Industry Standard CAD/CAM

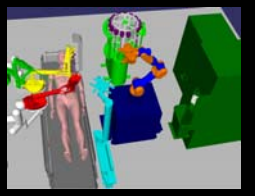
SIMULATION

Virtual Design

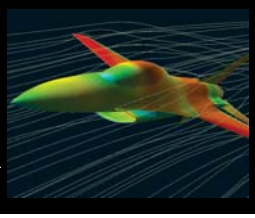


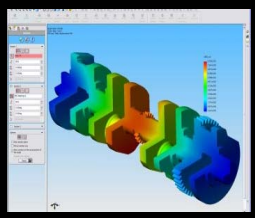
Virtual Prototyping





Virtual Testing & Evaluation





# It's Time to Transition

How we view the EMR - the Interface

Atari 1977

Mac 1984

**Healthcare has yet to realize the potential of high performance computing & simulation**

By 2015 a laptop will compute at 1 TeraHz - today's supercomputer

2015

Courtesy A. Tsiaras
Anatomic Travelogue

# Information Representation of a Patient

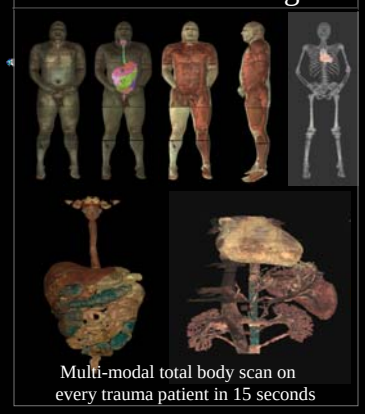
Medical equivalent of CAD/CAM

Virtual Soldier Program

## Holomer

Total body-scan

for total knowledge



Multi-modal total body scan on every trauma patient in 15 seconds

Satava March, 2004

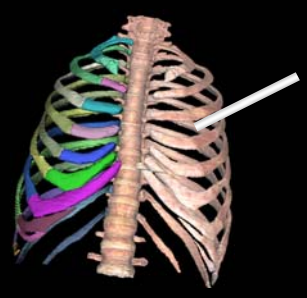
# The Revolutionary Change

## The Visual Medical Record

**Well, maybe not all people understand the importance of visualization**

# Virtual Autopsy . . .

. . . is a SIMULATED Autopsy



Less than 2% of hospital deaths have autopsy

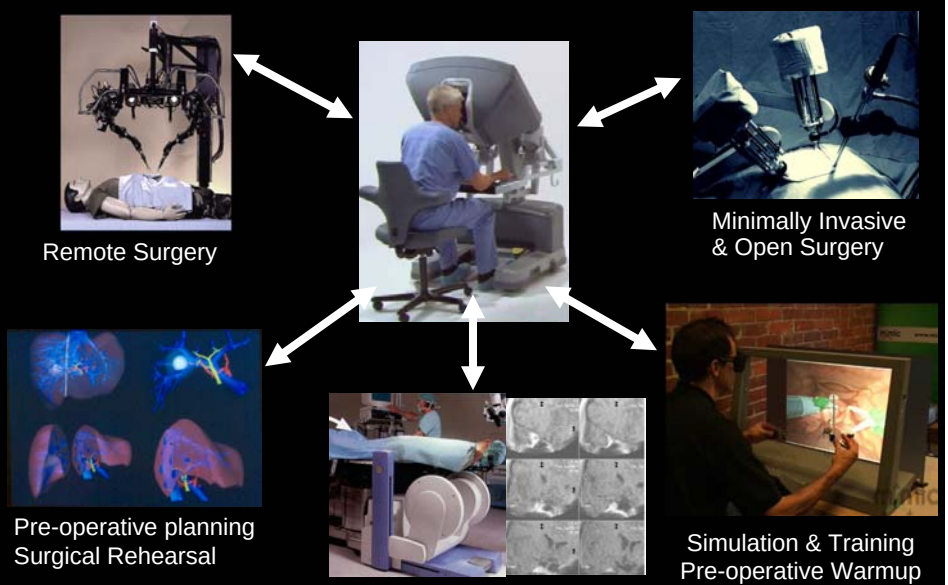
Statistics from autopsy drive national policies

## *Why modeling & simulation, imaging and robotics*

- Healthcare is the only industry without a computer representation of its "product"

- A robot is not a machine . . .
  it is an information system with arms . . .
- A CT scanner is not an imaging system
  it is an information system with eyes . . .
  thus
- An operating room is an information system with . . .

## Total Integration of Surgical Care




Courtesy of Joel Jensen,
SRI International, Menlo Park, CA

## The Fundamental Change

From tissue and instruments

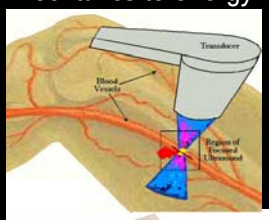
to

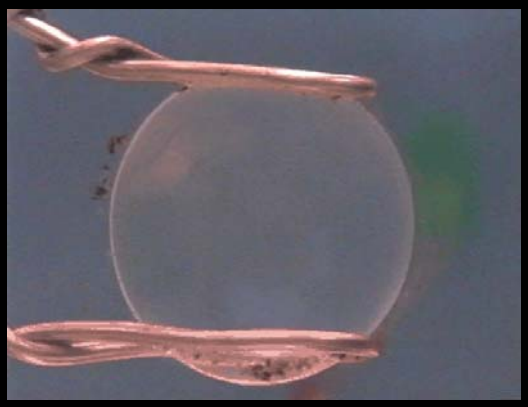
Information and energy*

* "The Information Age is about changing from objects and atoms to bits & bytes"
Nicholas Negroponte "Being Digital" - 1995

# Point-of-care Noninvasive Therapy

Mechanics to energy

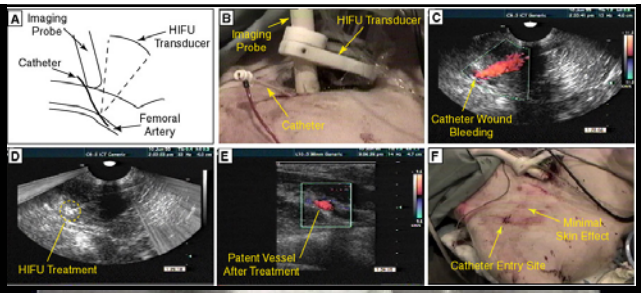




**HIFU**

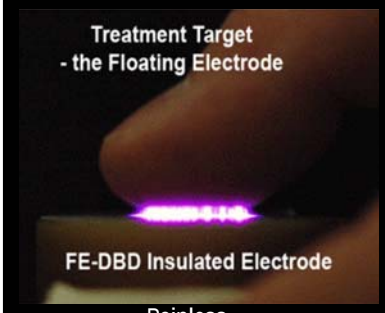
High Intensity Focused Ultrasound
for
Non-invasive Acoustic hemostasis

Courtesy Larry Crum, Univ Washington Applied Physics Lab

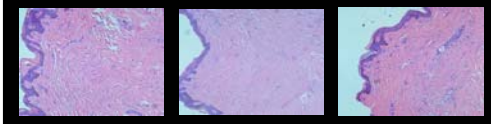


Courtesy Larry Crum, Univ Washington Applied Physics Lab 2003

# Sterilization without supplies




Painless

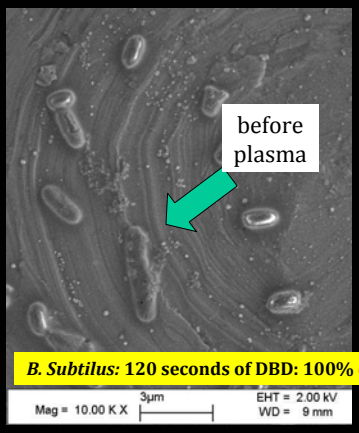


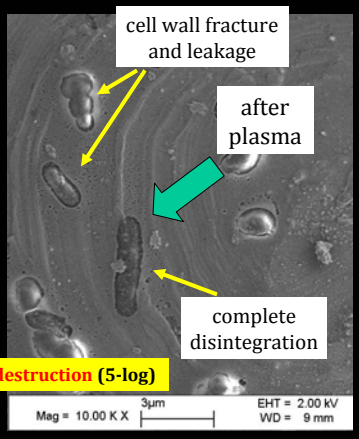
**Insure safety of other cells and tissues**

100% effective
30 sec, Continuous DBD, 8kHz
**Power: 0.8 W/cm²**

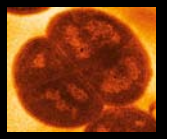
# Sterilization without supplies

Surface Sterilization from Bacillus Subtilis spores, Deinococcus radiodurans, B. anthracis spores, Acinetobacter, MRSA, E.Coli, Cyanobacteria, Streptococci, Staphylococci, Yeast, etc.



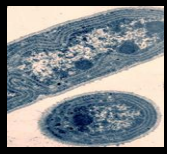




***B. Subtilus:*** **120 seconds of DBD: 100% destruction (5-log)**



***D. radiodurans***

**B. anthracis**



**Cyanobacteria**

# Treatment of Topical Wounds:

## Tissue Regeneration: Suppurated Burn Wound

**Before treatment**

**After 7 days of plasma therapy (5 sessions)**

Bring the hospital to the casualty, not the casualty to the hospital . . .

" . . . with a fully functional ICU "

# The LSTAT

## Life Support for Trauma and Transport

Courtesy of Integrated Medical Systems, Signal Hill, CA

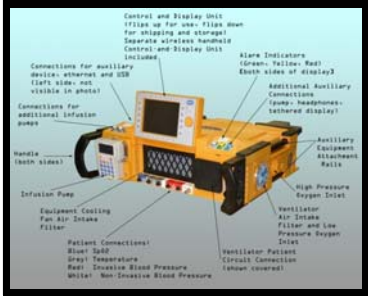
Total Patient Awareness

- **Defibrillator**
- **Ventilator**
- **Suction**
- **Monitoring**
- **Blood Chemistry Analysis**
- **3-Channel Fluid/Drug Infusion**
- **Data Storage and Transmission**
- **On-board Battery**
- **On-board Oxygen**
- **Accepts Off-Board Power and Oxygen**

# LSTAT Deployment to Kosovo - March 2000

**212th MASH Deployed with LSTAT - Combat Support Hospital**

LSTAT- *lite*



Courtesy of Integrated Medical Systems, Signal Hill, CA

# Why now?

**VTOL UAV technology is maturing rapidly enough to minimize risk.**

Aeromedical evacuation

# Nightingale UAV Goal

- Identify "optimum" VTOL UAV design
- Create a new VTOL UAV tailored to the operational need

# *Classic Education and Examination*

What is the *REVOLUTION* in Surgical Education?

# SURGICAL EDUCATION The Revolution

*is*

*. . . Now*

*Roughly 100 year cycles*

*(1908 – Flexner Report)*

# Skills Training

*The New Mandates*

| Effective | |
|---|---|
| 1 July 2008 RRC* | All residency programs must have a skills training (simulation) center |
| 1 July 2009 ABS | All surgical residents must pass FLS** in order to apply for board certificate |

* Residency Review Committee (RRC)

** Fundamentals of Laparoscopic Surgery

Accreditation Council of Graduate Medical Education
Approved by American Board of Medical Specialties

## ACS/APDS Core Curriculum

SCORE

Three Phases

| Phase | Product | Complete |
|---|---|---|
| •Phase1 | Basic Skills Curricula | July, 2007 |
| •Phase 2 | Full Procedures | July, 2008 |
| •Phase 3 | Team Training | July, 2009 |

## ABS Training/Assessment Website

Provides educational/training resources

Clearly states expected performance outcomes (quantitative)

## Why should we do this?

Historically — Medical education occurs in 100 yr cycles (Flexner 1910)
If don't act now, miss "window of opportunity"

Standardization — Everyone is "starting from scratch", so everyone must change
Unique opportunity to have 'International' standards

Paradigm Shift — Competency (criterion) based training and assessment
? Totally change structure of system (eg time-based)

## Ethical Implications

| | |
|---|---|
| Credentialing | every surgeon, every procedure? |
| Patient Safety | assurance for our patients? |
| Animals for training | still needed, but reduced? |
| Quality Assurance | promising too much? |

## Disruptive Technology in Surgery
## N.O.T.E.S.

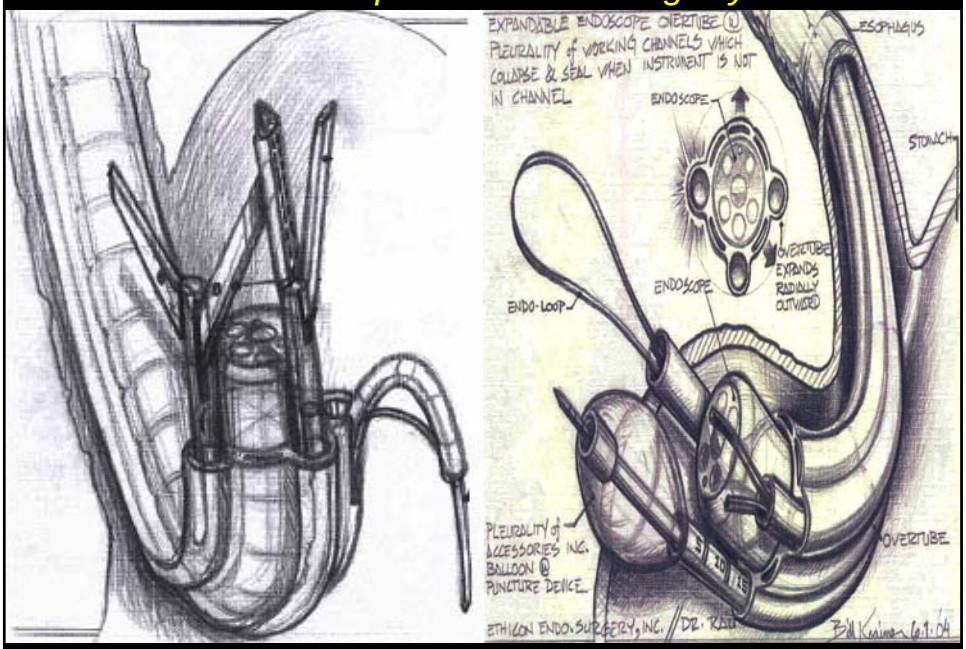
**Natural Orifice Transluminal Endoscopic Surgery**
**Trans-Gastric Surgery**

***New surgery for great new opportunities***

We need:

*New "tools" for the new procedures*
*New simulators for education and training*

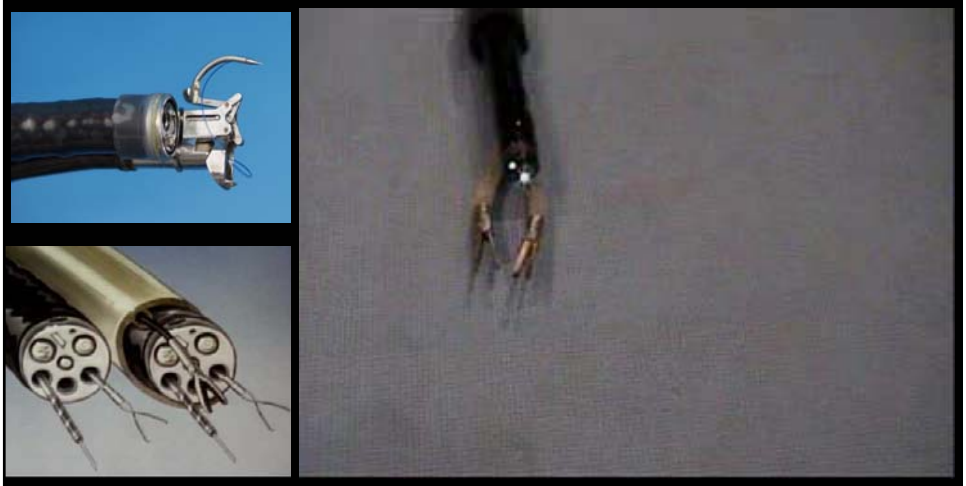
## Trans Oral Intra-peritoneal Surgery - Future




Courtesy of N Reddy, Hyperbad India 20005

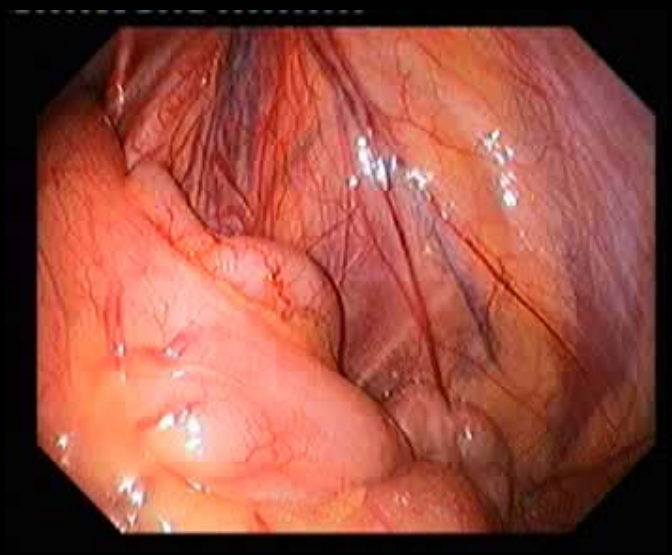
## Early Luminal Malignancies

### Robotic Endoscopic Mucosal Resection - EMR

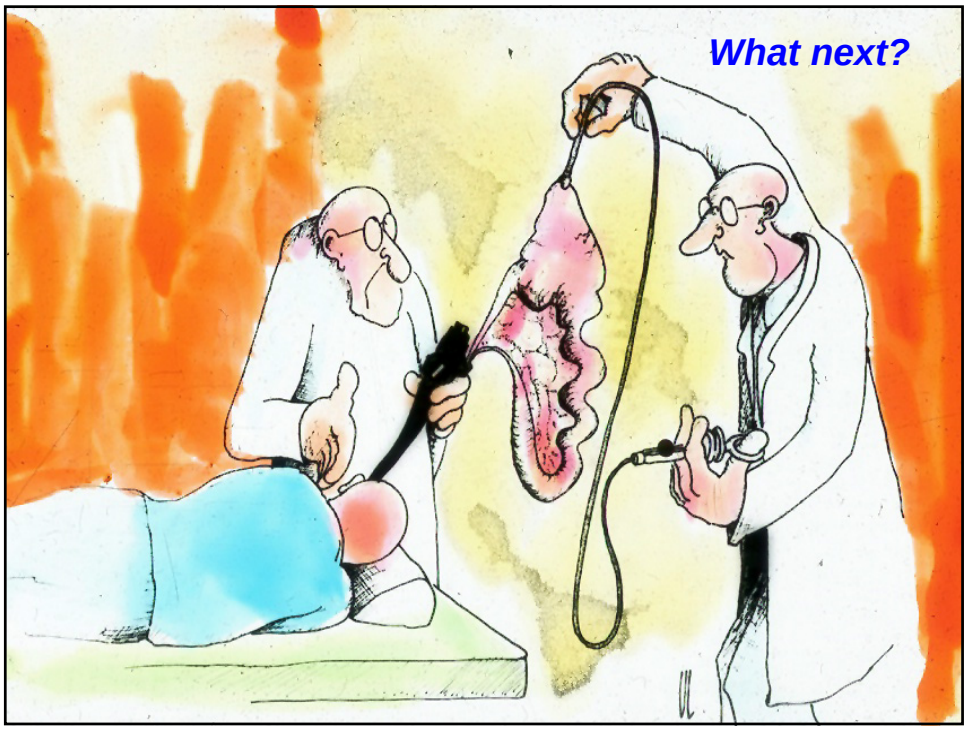


Courtesy of N Reddy, Hyperbad India 20005

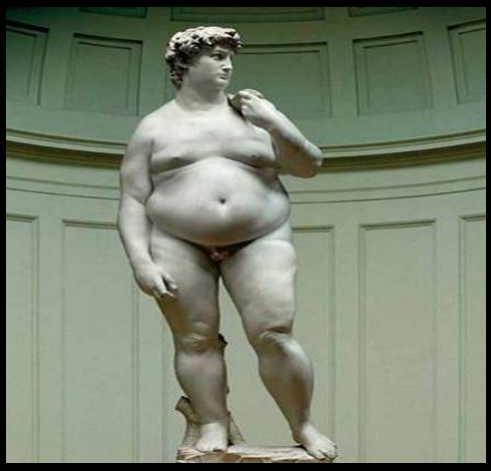
## *First Transgastric Appendectomy – N.O.T.E.S.*



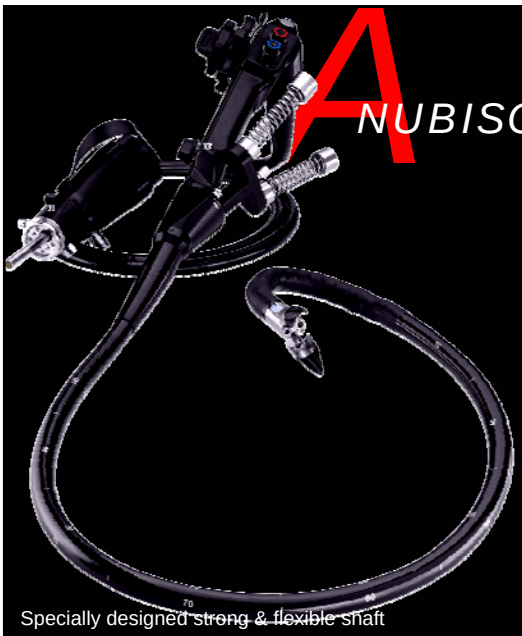
Courtesy of N Reddy, Hyberdad India 2005



# NOTES - for Bariatric Surgery



# ANUBISCOPE 2009



ANUBIS
Ancient Egyptian Godness
Bridging different worlds
real world and underworld
upper and lower Egypt
„Magic surgery“ during mumification
„Opening of the mouth“ ceremony

Specially designed strong & flexible shaft

- Shaft length/dia 110 cm / 16 mm
- Working channels: 4.2 mm (2) & 3.2 mm
- Full retroflexion 180°/180°

Courtesy Karl Storz Endoscopy, Tutlingen, Germany 2009

# ANUBISCOPE 2009

## Multifunctional Tip

Flaps closed

Flaps open

### Introduction and Dilatation

- gentle and soft like a closed tulip
- transoral, transesophageal insertion (other routes possible)
- vision & gastrotomy possible
- dilates the incision (like blunt trocar)
- builds a seal around the endoscope

### Unfolding the Flaps

- exposes system in the working position
- defines and creates the working space,
- reduces the risk to injure tissue out of the field of vision
- retracts surrounding organs
- guides instruments from the central position for triangulation
- open flaps are almost out of the field of vision

Courtesy Karl Storz Endoscopy, Tutlingen, Germany 2009

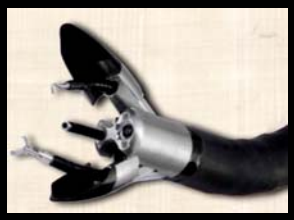
# ANUBISCOPE 2009

## Multifunctional Set-ups

Grasper and hook

Suturing set up

Grasper and Laser tool



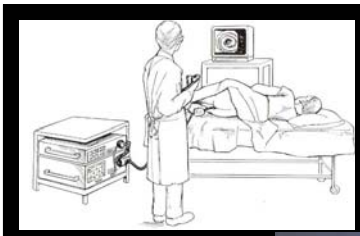
additional suction tool

Courtesy Karl Storz Endoscopy, Tutlingen, Germany 2009

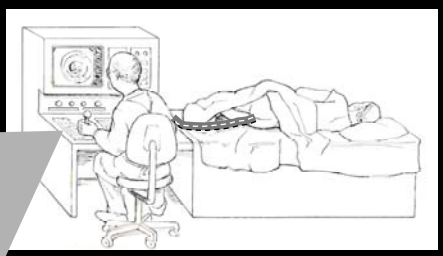
# N.O.T.E.S. COBRA DEVICE

Courtesy of Olympus Endoscopy - 2007

# Future EndoscopicWorkstation?



Conventional colonoscopy



Tele-endoscopy. Controlling micro-robot
(which has been inserted into the rectum)
from endoscope workstation

[ Courtesy R Satava, GI Clinics North America, 1983]

Endo-vascular work station – by Hansen Medical, Inc

URL http://hansenmedical.com Feb, 2007

# The Future is MEMS

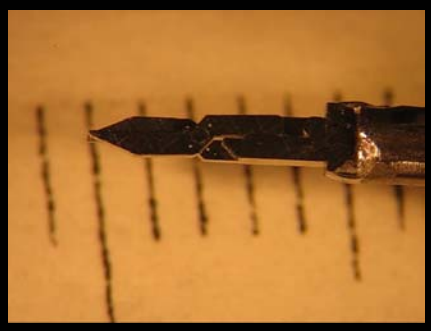
Biopsy forceps, 2 & 3 French (0.7 & 1 mm)

EFAB-Produced
Biopsy Forceps
(~ 1 mm width)

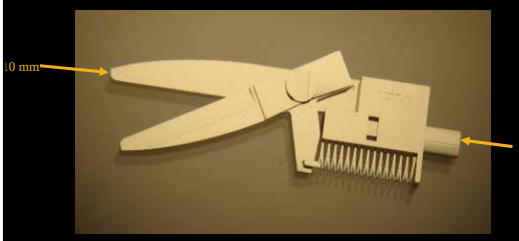
Courtesy MicroFab Inc, 2005

# The Future is MEMS

Scissors (0.5 & 1 mm)



Mechanical Scissors




Hydraulic Scissors

Courtesy MicroFab Inc, 2005

## Laparoscopic Sewing Machine

Courtesy of Karl Storz, Tutlingen, German 2008

## New Concepts for OR of the Future

"The OR Without Lights"

Eric LaPorta, Barcelona, Spain 2005

"Penelope" – robotic scrub nurse

Currently in Clinical Trials

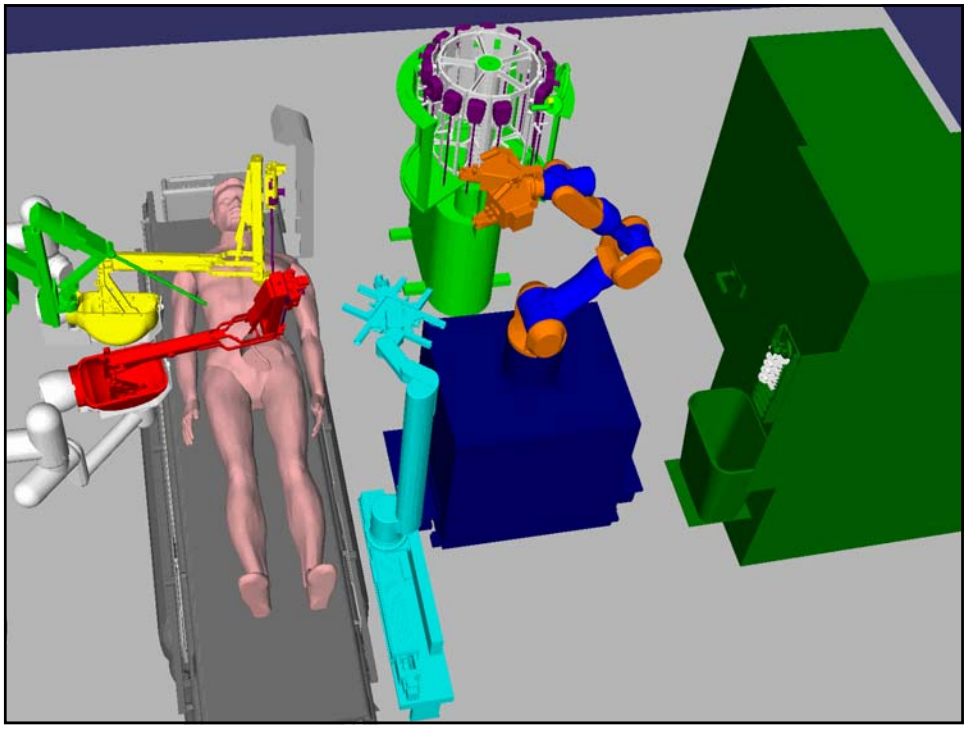
Michael Treat MD, Columbia Univ, NYC. 2003

## *Integrating Surgical Systems for Autonomy*

*The Operating Room (personnel) of the Future*

Surgeon Assistant Scrub Nurse Circulating nurse

Borrowing from the standard practices of other industries



**Demonstration of Phase 1**

## Operating Room with no People

SRI International, Menlo Park, CA January, 2007

Demonstration of Phase 1

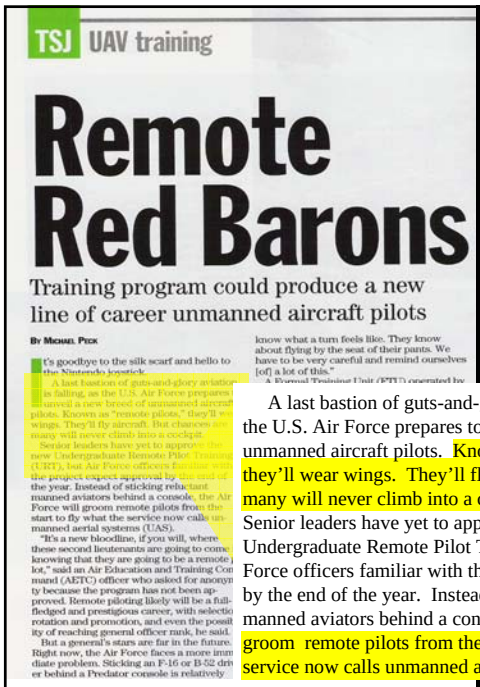
## Operating Room with no People

SRI International, Menlo Park, CA January, 2007

Fighter Pilots – until 2002

Predator 2003

Fighter Pilots – Beyond 2003



TSJ UAV training

# Remote Red Barons

Training program could produce a new line of career unmanned aircraft pilots

By Michael Peck

It's goodbye to the silk scarf and hello to the Nintendo joystick.

A last bastion of guts-and-glory aviation is falling, as the U.S. Air Force prepares to unveil a new breed of unmanned aircraft pilots. Known as "remote pilots," they'll wear wings. They'll fly aircraft. But chances are many will never climb into a cockpit.

Senior leaders have yet to approve the new Undergraduate Remote Pilot Training (URT), but Air Force officers familiar with the project expect approval by the end of the year. Instead of sticking reluctant manned aviators behind a console, the Air Force will groom remote pilots from the start to fly what the service now calls unmanned aerial systems (UAS).

"It's a new bloodline, if you will, where these second lieutenants are going to come knowing that they are going to be a remote pilot," said an Air Education and Training Command (AETC) officer who asked for anonymity because the program has not been approved. Remote piloting likely will be a full-fledged and prestigious career, with selection rotation and promotion, and even the possibility of reaching general officer rank, he said.

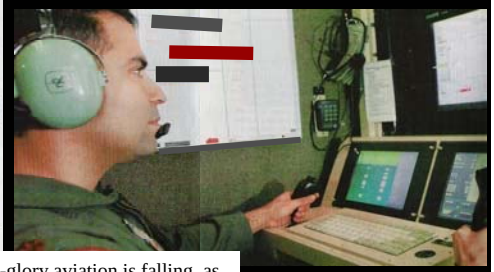
But a general's stars are far in the future. Right now, the Air Force faces a more immediate problem. Sticking an F-16 or B-52 driver behind a Predator console is relatively

know what a turn feels like. They know about flying by the seat of their pants. We have to be very careful and remind ourselves [of] a lot of this."

A Pilot Training Unit (PTU) operated by

28 Training & Simulation Journal August/September 2006

## "Remote Pilots"



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# *Robotic Medical Assistant*

Nursing shortage crisis

Applicable at all levels
- Hospitals
- Clinics
- Nursing Home
- Assisted living

Courtesy Yulun Wang, InTouch Technologies, Inc, Goleta, CA

# Radiology or Surgery?

Accuray
(Cyberknife)

Non-invasive tumor ablation for solid organs (0.3mm accuracy)

Surgeon should be part of planning and implementation team

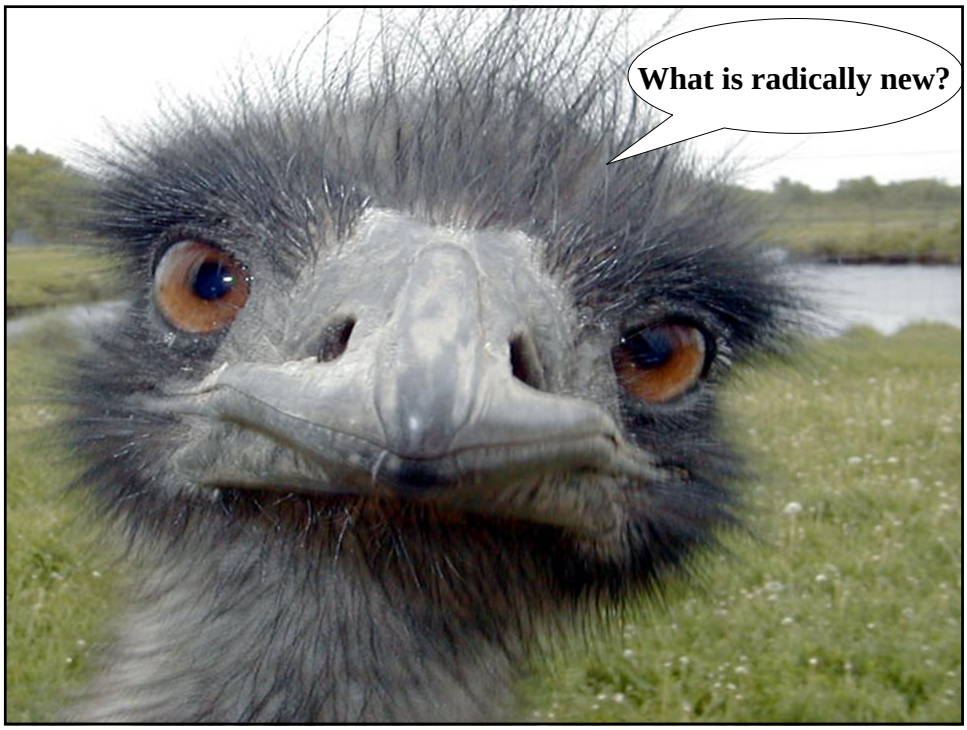
Surgeons may want to ‘adopt’ implementation

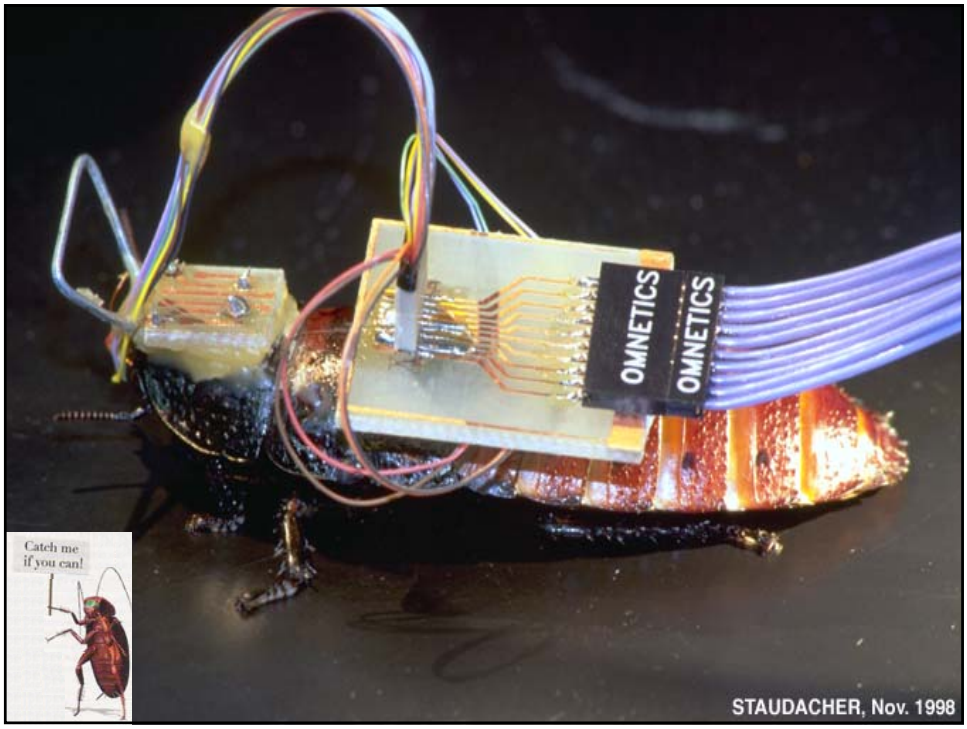
# REAL FUTURE

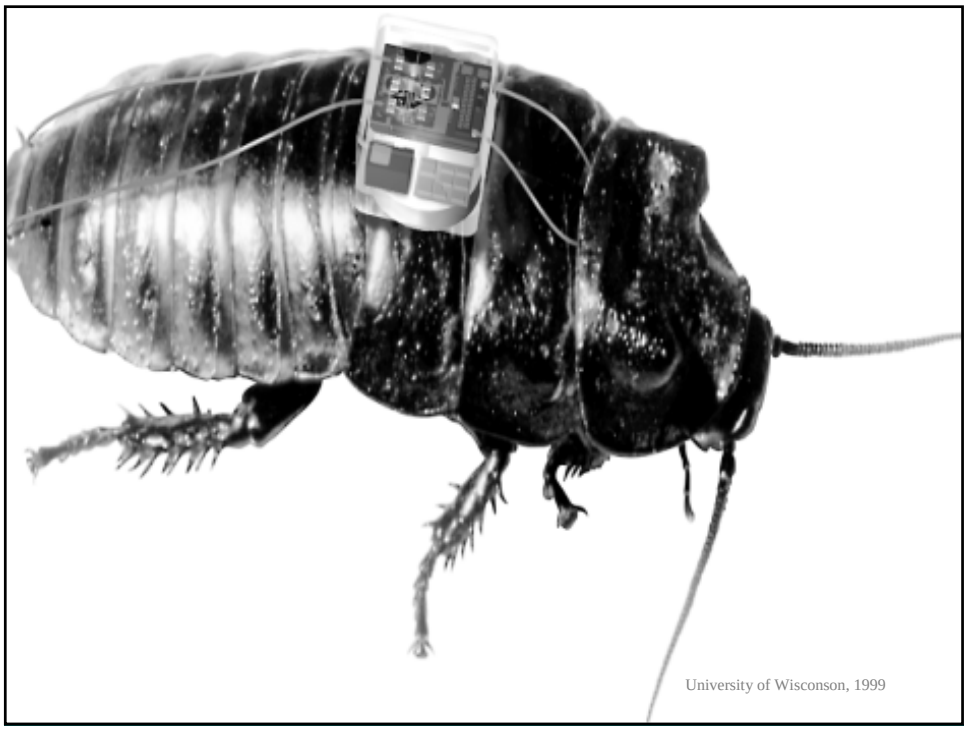
The Information Age is NOT the Future

The Information Age is the Present ...

There is something else out there . . . .




OMNETICS
OMNETICS
Catch me
if you can!
STAUDACHER, Nov. 1998


University of Wisconson, 1999

# Biomimetic Micro-robot

Courtesy Sandia National Labs

Courtesy Danny Scott
Texas Southwestern
Dallas, TX

Courtesy D. Oleynkov, Univ Nebraska

Capsule camera for gastrointestinal endoscopy

Courtesy Paul Swain, London, England

**Research and expectations on capsular endoscopy in diagnosis and therapy**

***Eliminating gastrointestinal cancers through breakthrough medical microtechnology***

**Supported by the European Union as an Integrated Project**
**Information Society Technologies - Contract Number 033970**
**www.vector-project.com**

VECTOR

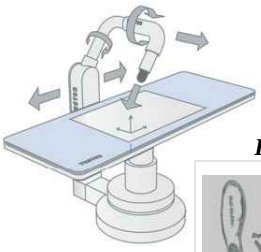
**Courtesy Marc O. Schurr &**
**The VECTOR consortium - 2008**

# Self-propelling Gastrointestinal Endoscope
## Core functions

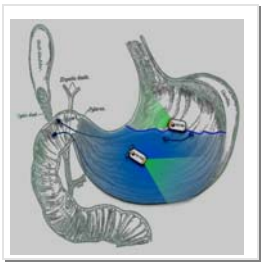
Locomotion

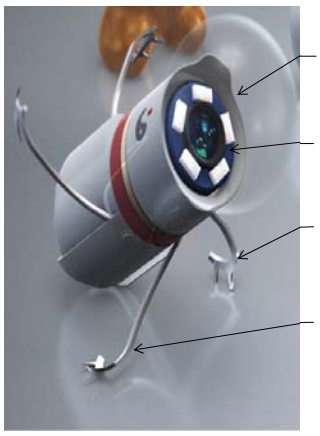
Modular functions

***External magnetic guidance***



***Fluid environment***





**Core capsule systems:** optical system, telemetry and power systems, navigation etc.

**Diagnostic system:** sensors for enhanced diagnosis

**Therapeutic / biopsy system:** devices for tissue manipulation

**Locomotion system:** actuators for mobility.

**Supported by the European Union as an Integrated Project**
**Information Society Technologies - Contract Number 033970**
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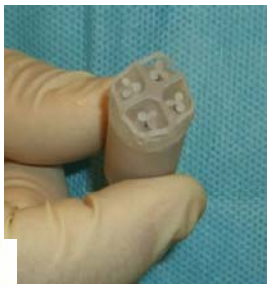
VECTOR

**Courtesy Marc O. Schurr &**
**The VECTOR consortium - 2008**

# Internal Locomotion Actuators Currently Investigated

***Walking robot with legs***

***Submarine***



***Vibratory locomotion***

**Source (both): A Menciassi et al., CRIM, Scuola Sant'Anna, Pisa**

**Source: M. Sfakiotakis et al., FORTH, Heraklion**

**Supported by the European Union as an Integrated Project**
**Information Society Technologies - Contract Number 033970**
**www.vector-project.com**

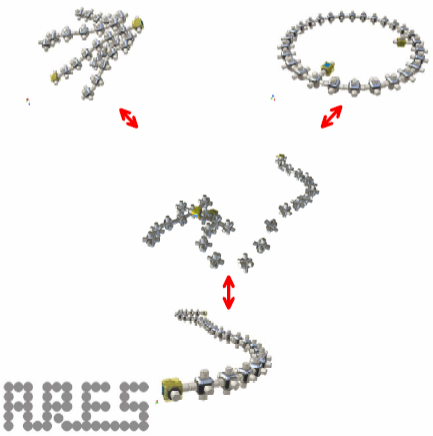
VECTOR

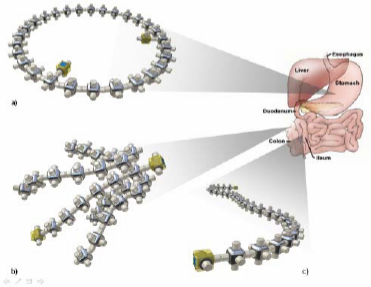
**Courtesy Marc O. Schurr &**
**The VECTOR consortium - 2008**

# A revolutionary idea…

A customizable self assembled and self reconfigurable robot…

… able to adapt its configuration to the specific site of intervention and to the task that must be executed






# *Femtosecond Laser*

*(1 x 10 $^{-15}$ sec)*

Los Alamos National Labs, Los Alamos NM

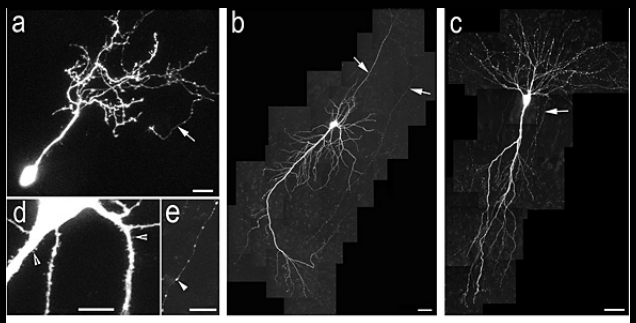
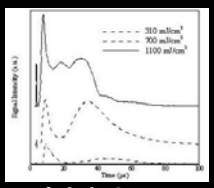
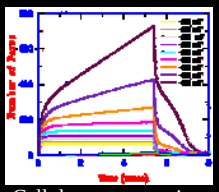



**Figure 1. a) Single-cell electroporation of pGFP *in vivo* in the Xenopus tadpole brain. SCE of CA1 (b) and CA3 (c) pyramidal cells in organotypic rat hippocampal slices. d) Enlargement of the CA1 pyramidal cell showing spines, and axonal varicosities (e).**

Cold Spring Harbor Laboratory, Long Island, NY

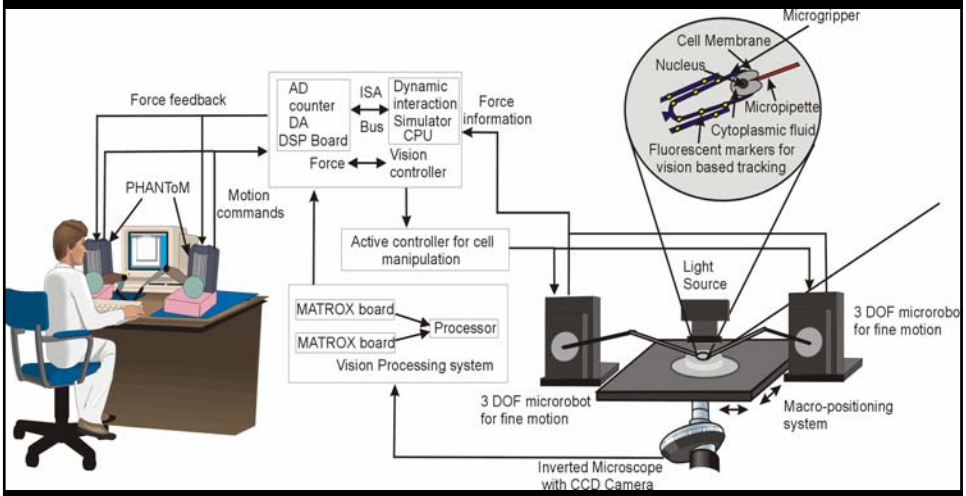


Time of Flight Spectroscopy



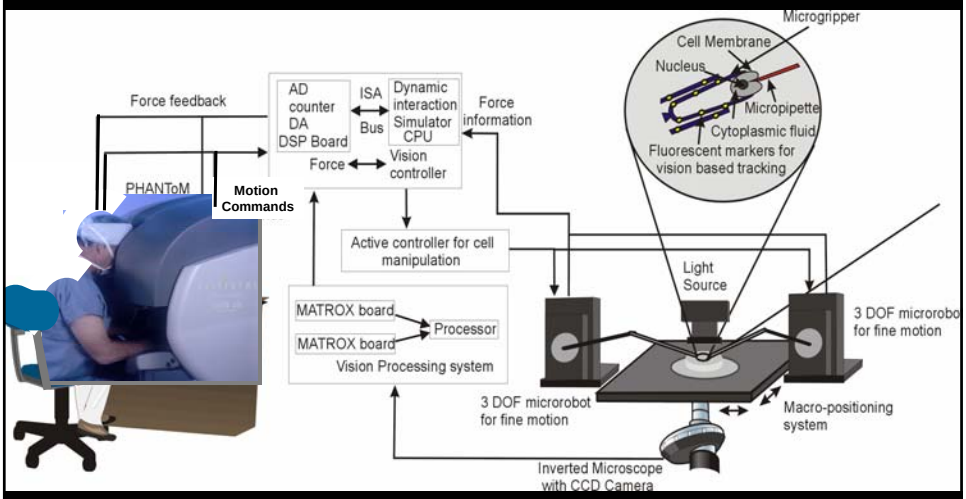
Cellular opto-poration

# Surgical Console for Cellular Surgery




Courtesy Prof Jaydev Desai, Drexel Univ, Philadelphia, PA 2005

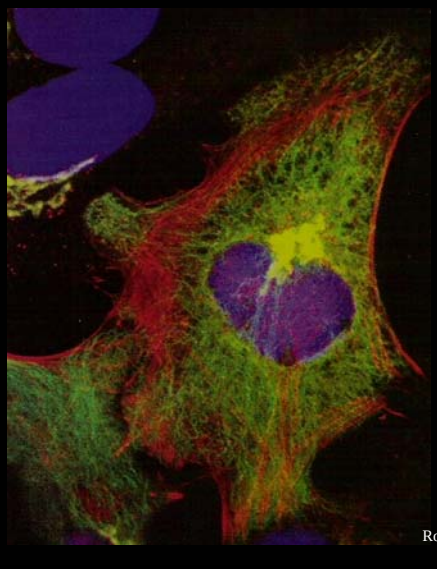
# Surgical Console for Cellular Surgery




Courtesy Prof Jaydev Desai, Drexel Univ, Philadelphia, PA 2005

Simulataneous multifunctional –
6 different fluorophores in a cell

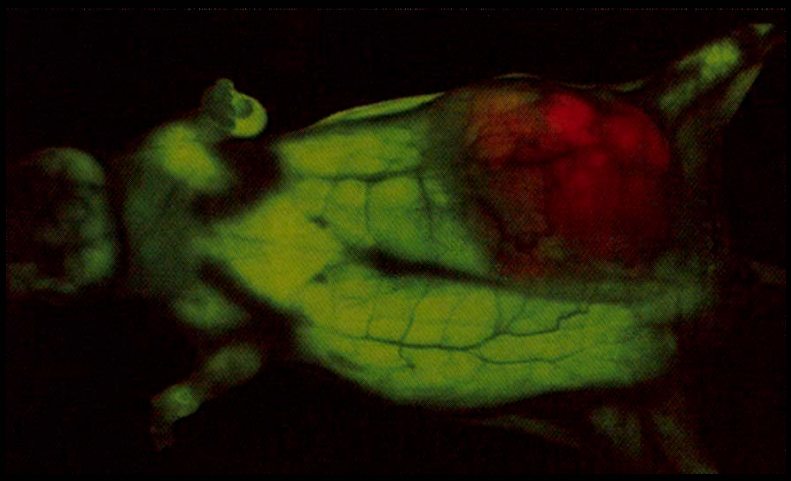
## Monitoring



Roger Tsien, UC-San Diego, La Jolla, CA 2006

## Monitoring

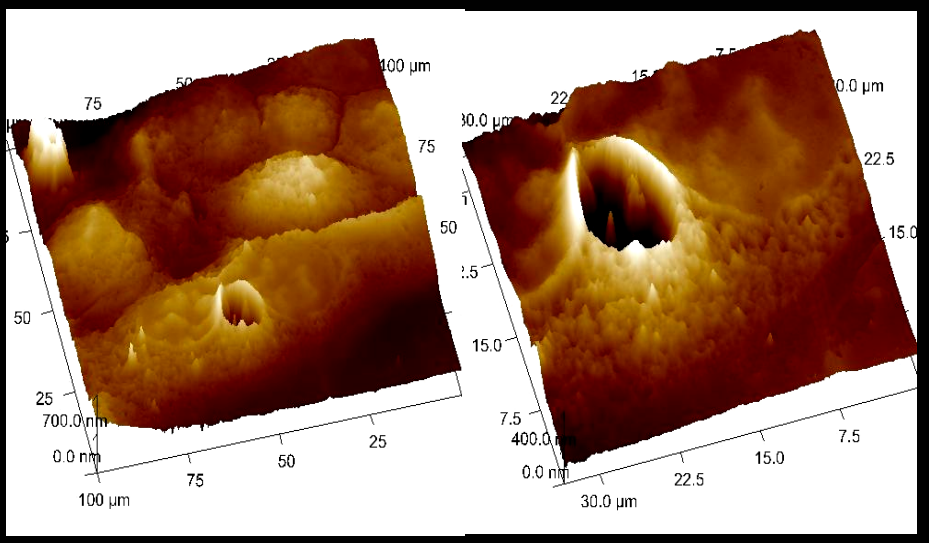
### Whole body visualization



Fluorescent antibodies (GFP and anti-tumor) – rat model

## Atomic Force Microscopy AFM

### Sonoporation of an ion channel



# New Surgical Tools

Atomic Force Microscope Manipulator
Femtosecond Lasers

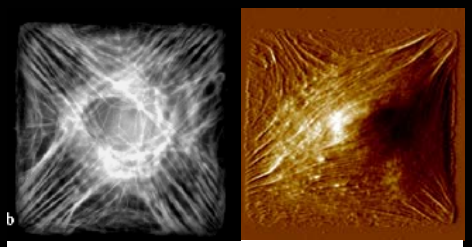



Fig. 2. Top: Fluorescent micrograph of the actin cytoskeleton of an engineered striated muscle cell. Bottom: AFM-acquired topographical map. Wrinkles and lines along the diagonals of the 30 micron square are actin stress fibers under the lipid membrane surface.

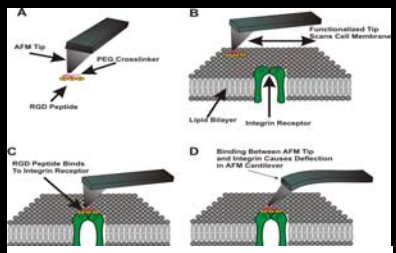



Fig. 3. Schematic illustrating the technique for functionalizing AFM tips to identify specific molecules on the cell surface during raster scanning.

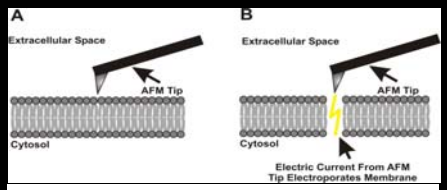
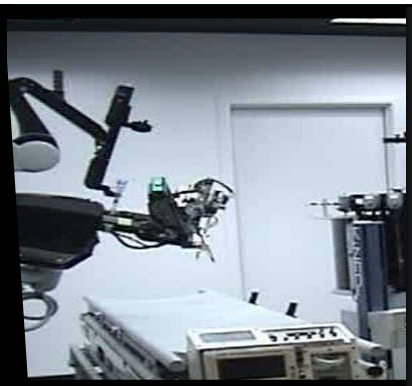
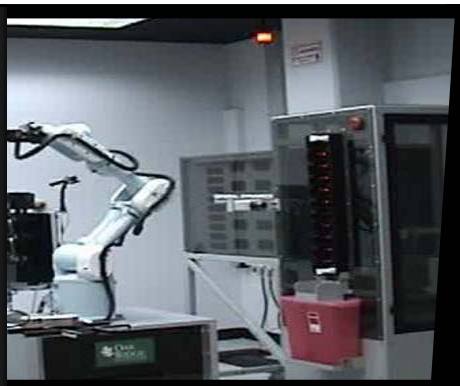


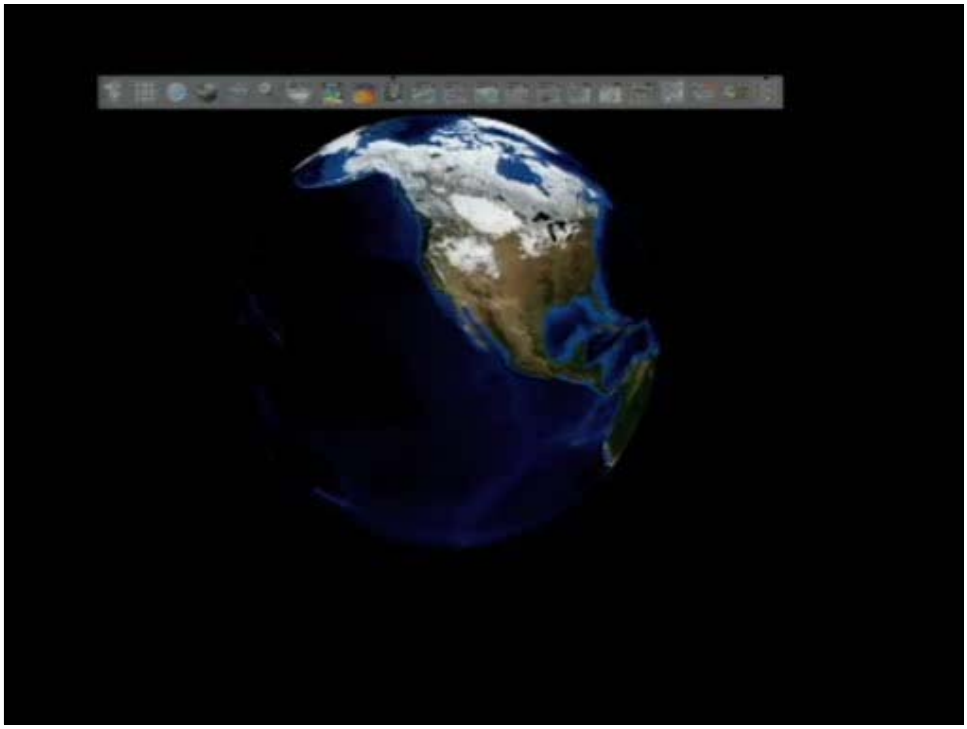

Fig. 4. Nanoincision by electroporation.
(A) The AFM cantilever is positioned above a region of interest in the cell.
(B) Electrical current is injected through the cantilever tip, causing the formation of a nanometer scale pore in the membrane, thru which the AFM tip can be dropped, or other instrumentation attached to the tip, prior to the membrane resealing.

Courtesy Prof Kit Parker, MD, Harvard Univ, Boston, MA 2005

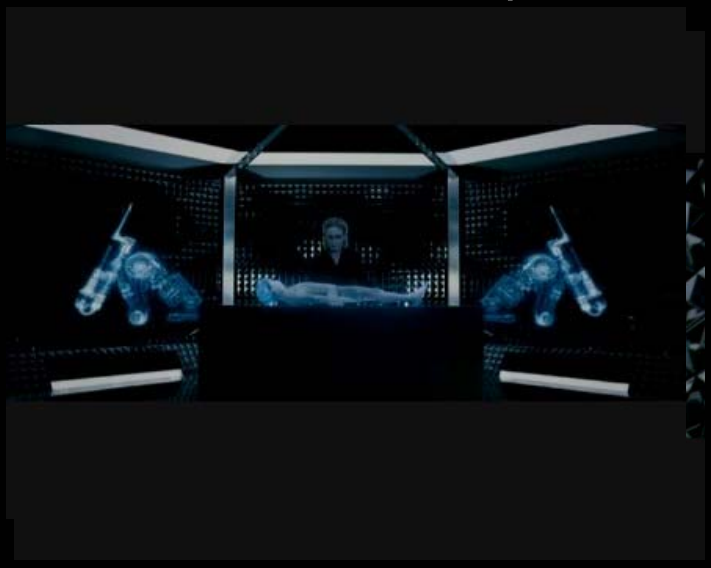




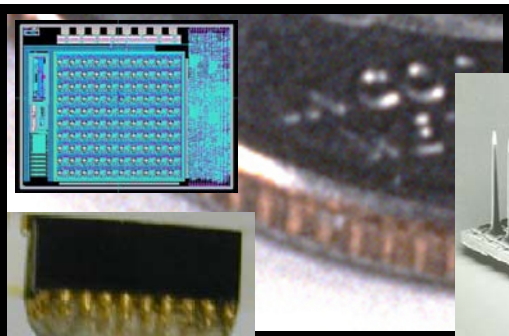
## Surgical Cockpit

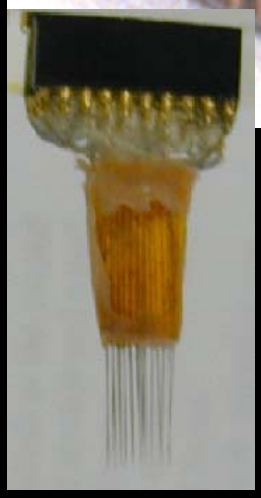


## Simulated Tele-operation

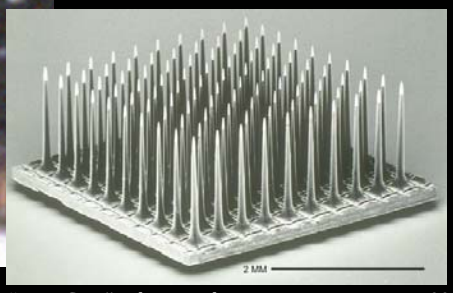


*Chrysalis* directed by Julien Leclercq. October 2007

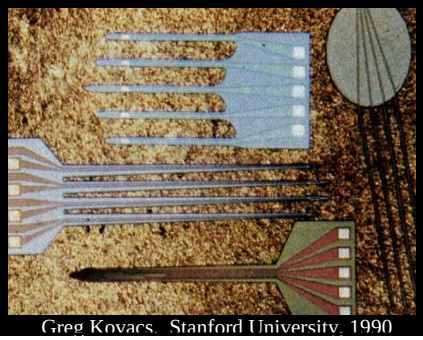




Richard Andersen, CalTech, 2003



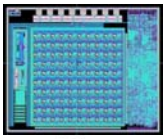

"BrainGate" John Donohue, Brown University, 2001

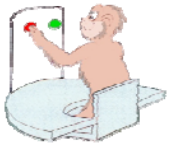


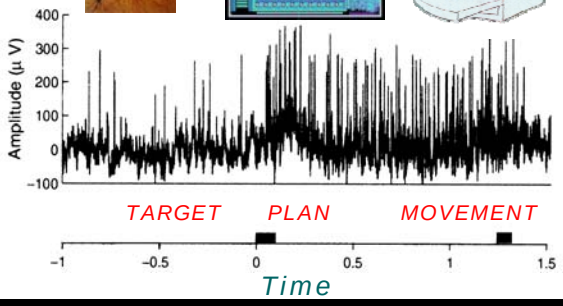
Greg Kovacs, Stanford University, 1990

# Brain Machine Interface – Controlling motion with thoughts

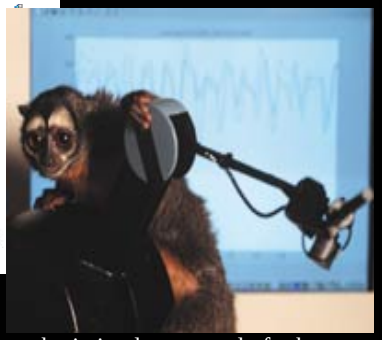
Recorded activity for intended movement to a briefly flashed target.





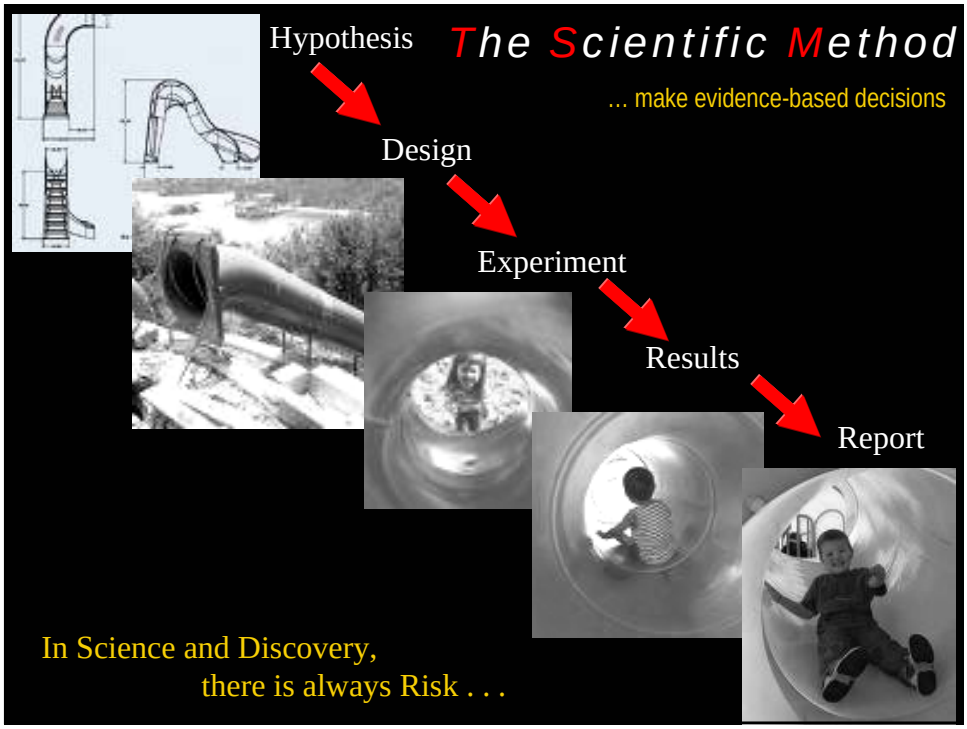



Courtesy Richard Andersen, Cal Tech, Pasadena, CA



Direct brain implant control of robot arm

Miguel Nicholai, Duke University, 2002




# Be careful of unintended consequences

Experience is the name everyone gives to their mistakes - Oscar Wilde

The only thing more dangerous than trying too hard and failing …
… is not trying hard enough and succeeding ! Michelangelo 1503

*Do Robots Dream ?*

http://depts.washington.edu/biointel