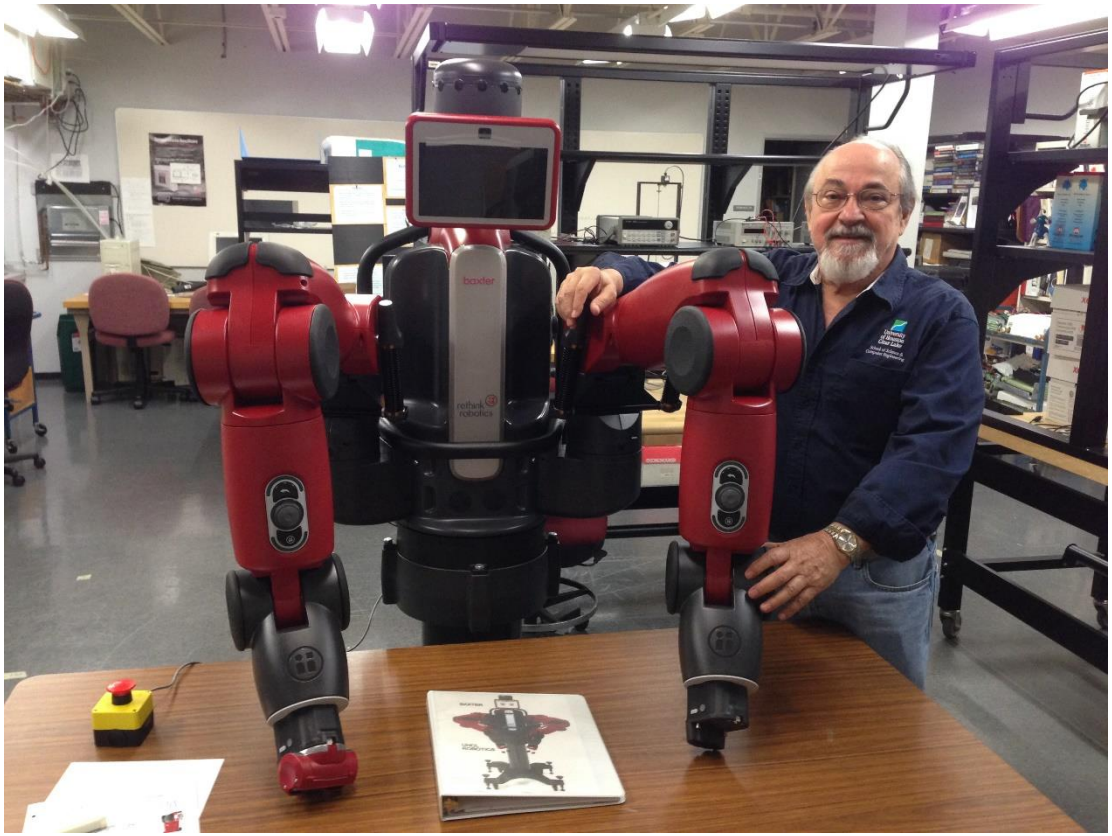
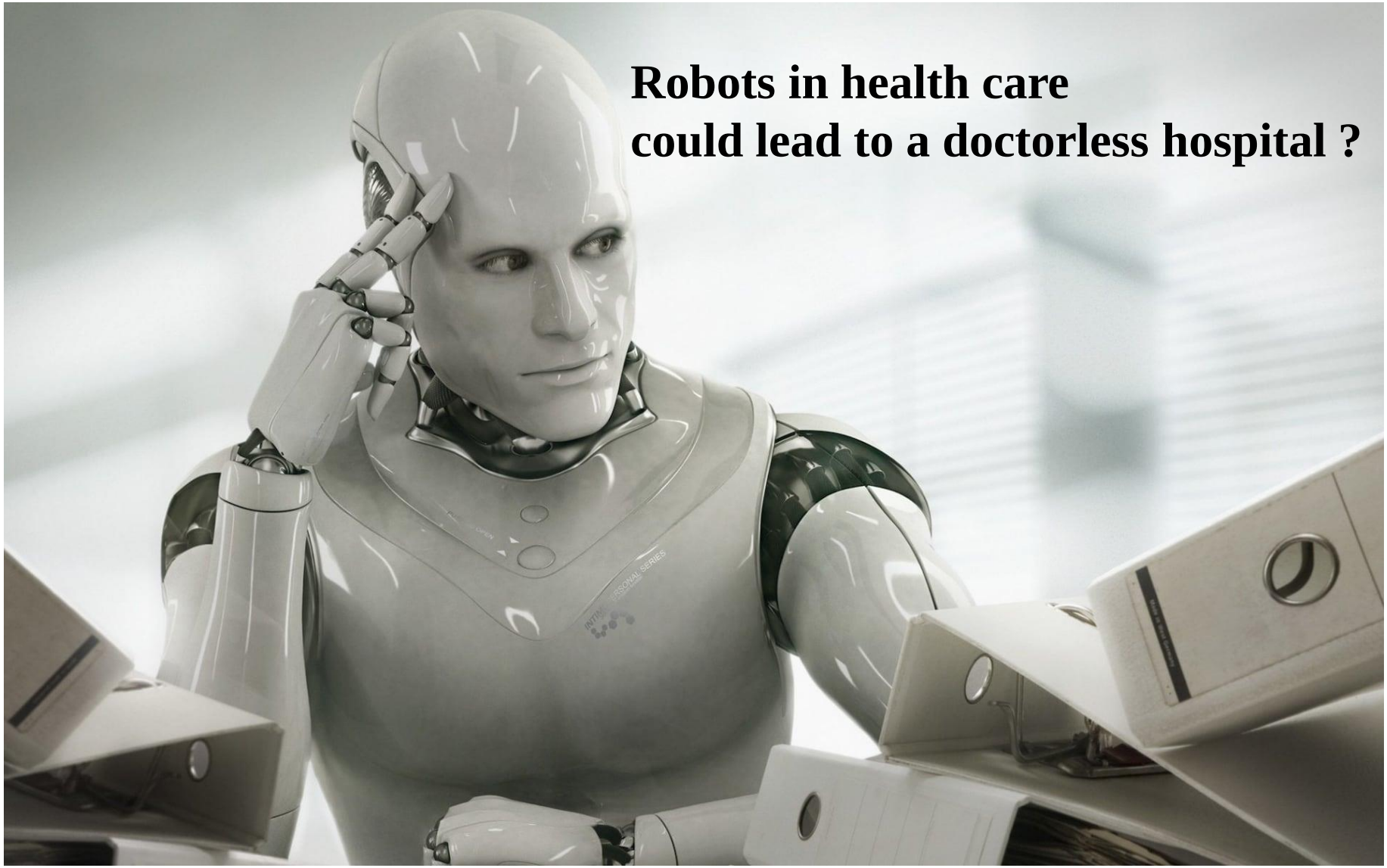
# Robots in the Doctor's Office and Beyond

**Thomas L. Harman, Ph.D.**
Director of Center for Robotics Software,
Department Chair of Engineering
Professor of Computer Engineering,






10 Aug 2017

- Business

Where should I cut?

# OUTLINE

- GENERAL
- APPLICATIONS
- ROBOT SPECIFICATIONS
- RESEARCH WORK
- SOCIAL ROBOTS
- THE FUTURE
- ENGINEERING CONTRIBUTIONS

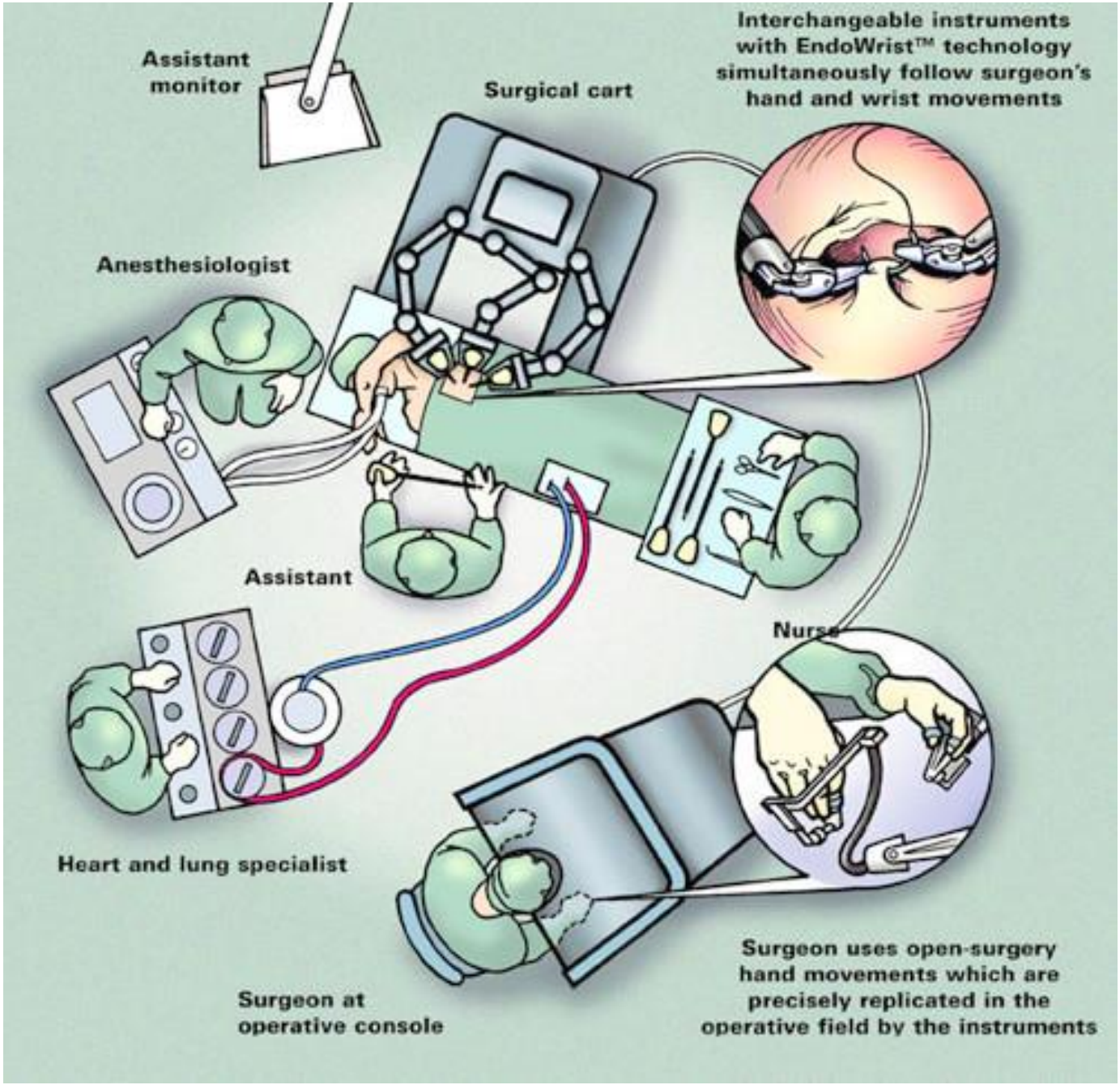
# Brief History

- 1921 - The term "robot" was first used in a play called "R.U.R." or "Rossum's Universal Robots" by the Czech writer Karel Capek. The plot was simple: man makes robot then robot kills man!
- 1941 - Science fiction writer Isaac Asimov first used the word "robotics" to describe the technology of robots.
  - A robot may not injure a human being or, through inaction, allow a human being to come to harm.
  - A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
  - A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.
- 1958 - The transition from science fiction to reality occurred in when General Motors introduced the Unimate to assist in automobile production.

# APPLICATIONS

- SURGERY
- ASSISTANCE
- PROSTHETIC DEVICES
- REMOTE SURGERY & TELECOMMUNICATION
- MILITARY

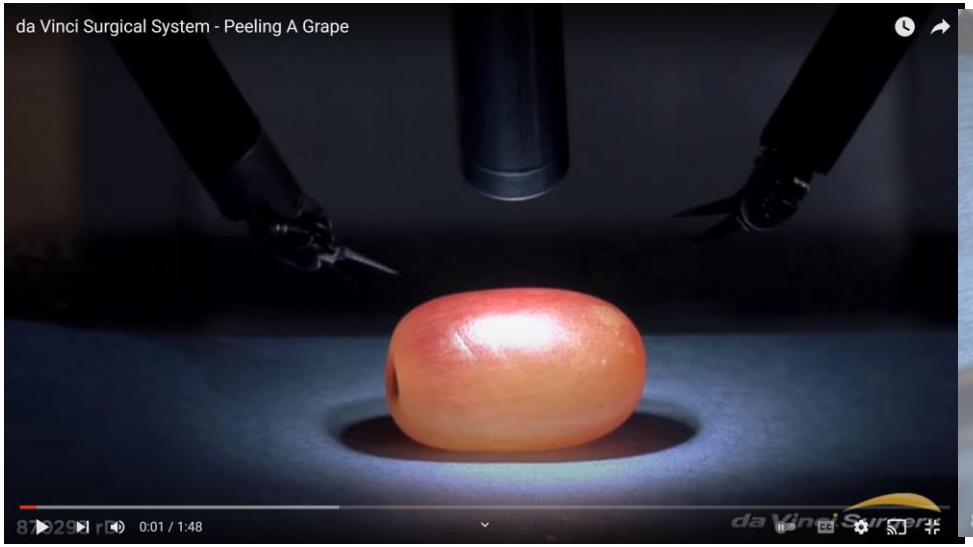
Teleoperated robot-assisted surgical system for minimally invasive procedures. (Credit: Intuitive Surgical, Inc.)

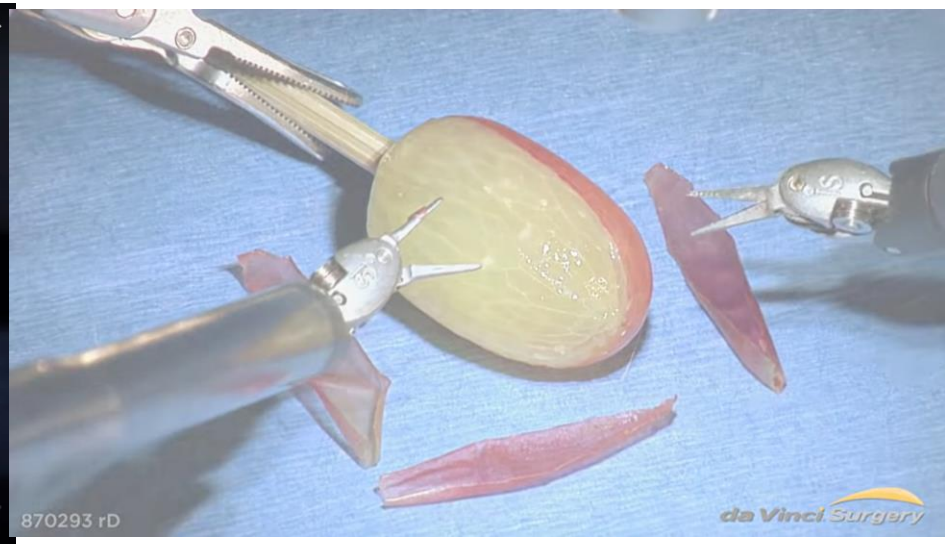

Assistant monitor
Surgical cart
Interchangeable instruments with EndoWrist™ technology simultaneously follow surgeon's hand and wrist movements
Anesthesiologist
Assistant
Nurse
Heart and lung specialist
Surgeon at operative console
Surgeon uses open-surgery hand movements which are precisely replicated in the operative field by the instruments

# UTMB daVinci System

# da Vinci Surgical System - Peeling A Grape

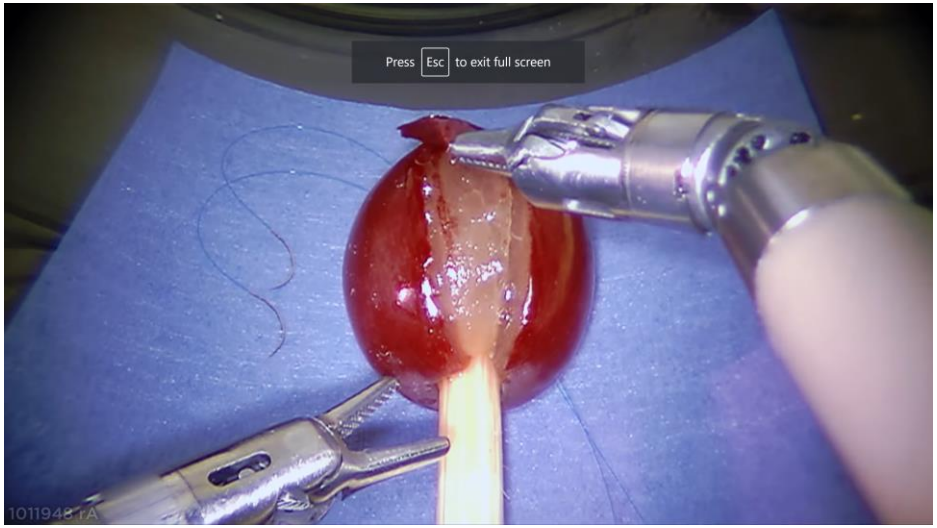
https://www.youtube.com/watch?v=-XRFe0nupM8

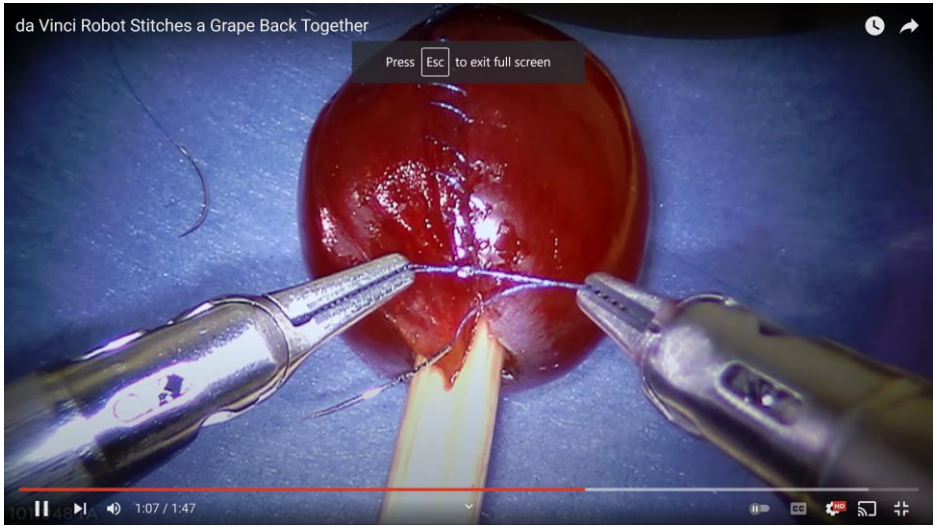


# Impressive? Watch this!

https://www.youtube.com/watch?v=0XdC1HUp-rU



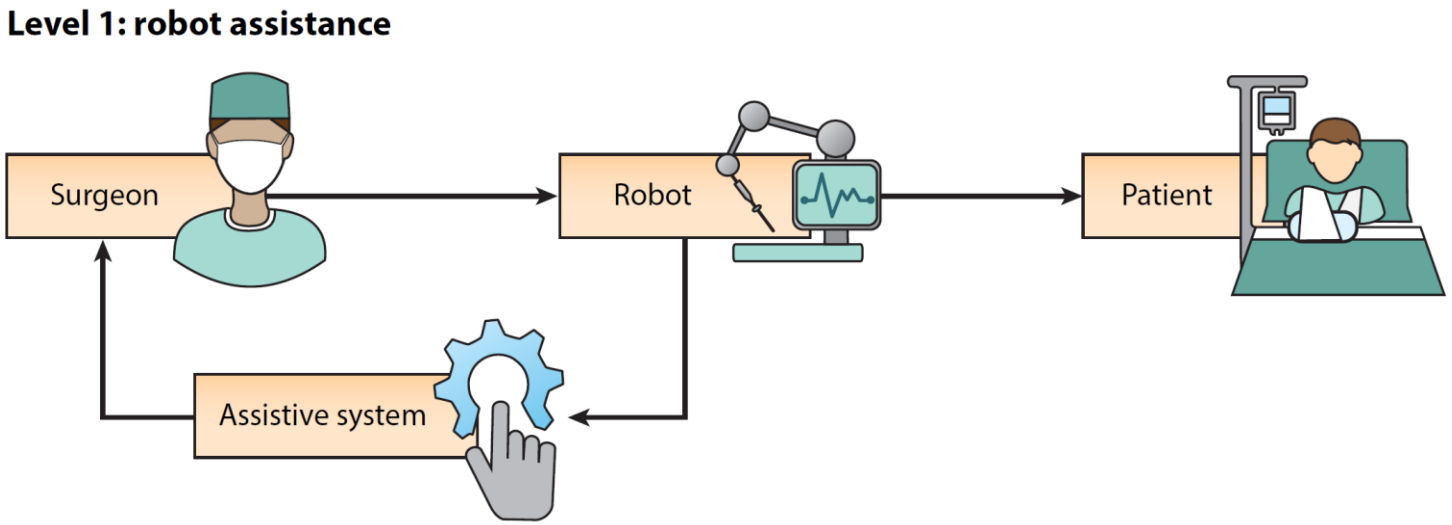



# LEVELS OF AUTONOMY

**At level 0**, where the bulk of commercial platforms are, the robot has no decision autonomy.

**At level 1**, the robot can provide cognitive and physical assistance to the surgeon, while at level 2, it can autonomously perform a surgical task.
**At level 2** (task autonomy) are capable of accomplishing specific surgical tasks based on specifications provided by the surgeon.
**Level 3** comes with conditional autonomy, enabling the robot to plan a task and update planning during execution.

Finally, robots at **level 4** can plan and execute a sequence of surgical tasks autonomously.




**At level 1**, the robot can provide cognitive and physical assistance to the surgeon, while at level 2, it can autonomously perform a surgical task.

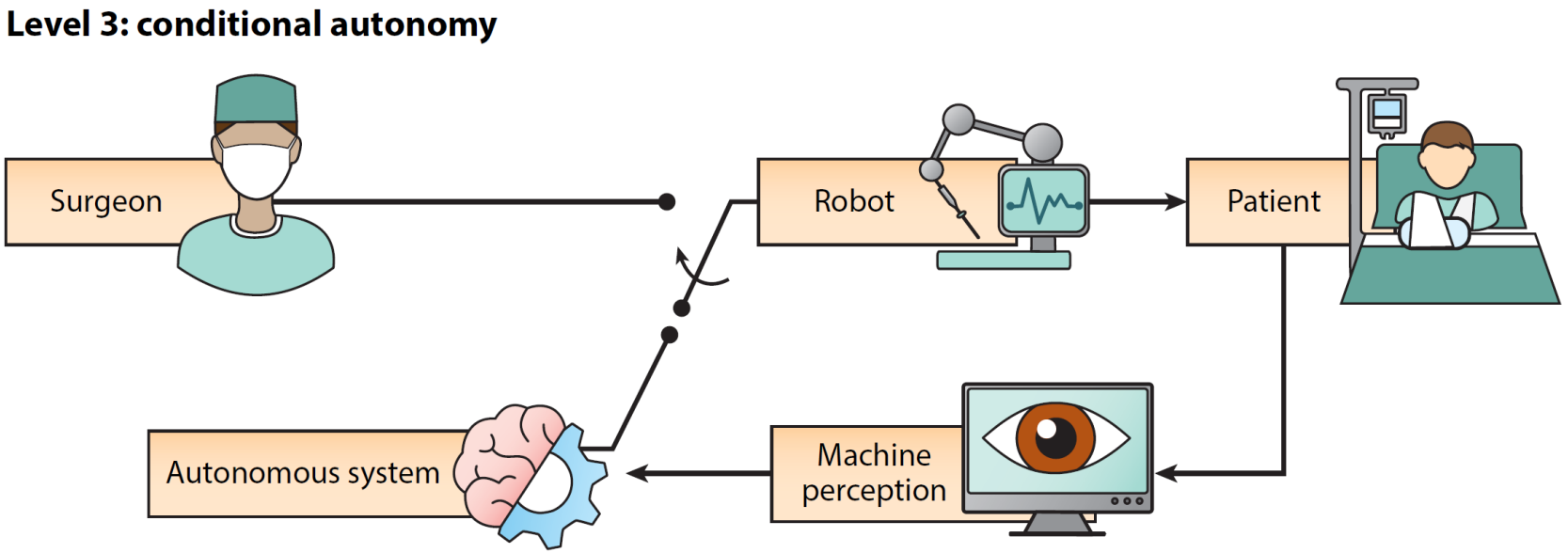



**Figure 6**

The role of a level-3 system in surgery. In contrast to level-2 systems, where the surgeon provides the specifications for a surgical task to be performed, level-3 systems can define the specifications autonomously. As in level-2 systems, level-3 systems have discrete control, as represented by the switch.

**Systems at level 5** (full autonomy) can perform surgery on their own with no human input.

**Systems at level 5** (full autonomy) can perform surgery on their own with no human input. This level is not discussed in this review because no systems have reached this level.

# Autonomy in Surgical Robotics 2021

Aleks Attanasio,[1] Bruno Scaglioni,[1] Elena De Momi, Paolo Fiorini,[3] and Pietro Valdastri[1]

A robot has performed laparoscopic surgery on the soft tissue of a pig without the guiding hand of a human -- a significant step in robotics toward fully automated surgery on humans. Designed by a team of Johns Hopkins University researchers, the Smart Tissue Autonomous Robot (STAR) is described today in *Science Robotics*. January 2022

# LEVELS OF DRIVING AUTOMATION

| 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **NO AUTOMATION** | **DRIVER ASSISTANCE** | **PARTIAL AUTOMATION** | **CONDITIONAL AUTOMATION** | **HIGH AUTOMATION** | **FULL AUTOMATION** |
| Manual control. The human performs all driving tasks (steering, acceleration, braking, etc.). | The vehicle features a single automated system (e.g. it monitors speed through cruise control). | ADAS. The vehicle can perform steering and acceleration. The human still monitors all tasks and can take control at any time. | Environmental detection capabilities. The vehicle can perform most driving tasks, but human override is still required. | The vehicle performs all driving tasks under specific circumstances. Geofencing is required. Human override is still an option. | The vehicle performs all driving tasks under all conditions. Zero human attention or interaction is required. |

THE HUMAN MONITORS THE DRIVING ENVIRONMENT

THE AUTOMATED SYSTEM MONITORS THE DRIVING ENVIRONMENT

# Features of Surgery Robot Assistant

- TELEOPERATED BY SURGEON
- MINIMALLY INVASIVE SURGERY
  USING ENDOSCOPES
- PRECISE MOVEMENT OF INSTRUMENTS
- EXAMPLES: Heart valve repair; stomach surgery;
  cutting and suturing; prostate removal, etc.

LEVEL: Direct control

CyberKnife Radiation Treatment
ACCURAY.COM

CyberKnife® is a non-invasive option for patients who have inoperable or surgically complex tumors, or who may be looking for an alternative to surgery. The CyberKnife system enables our radiation oncologists to deliver targeted, high doses of radiation to a broad range of tumors throughout the body.

Potential benefits of the CyberKnife system include:

- No incision
- No pain
- No anesthesia or hospitalization
- Greater comfort (patient can breathe normally during treatment)
- Little or no recovery time
- Immediate return to normal activities

# ASSISTANCE

- Disinfecting and General Service
- Lab Work – Fast and Accurate
- Baxter controlled by Brain Waves
- Rodent thinks and eats!
- Robots help in the Hospital
- IBM Watson Checks your health


https://www.youtube.com/watch?v=ntvhII_EjzA

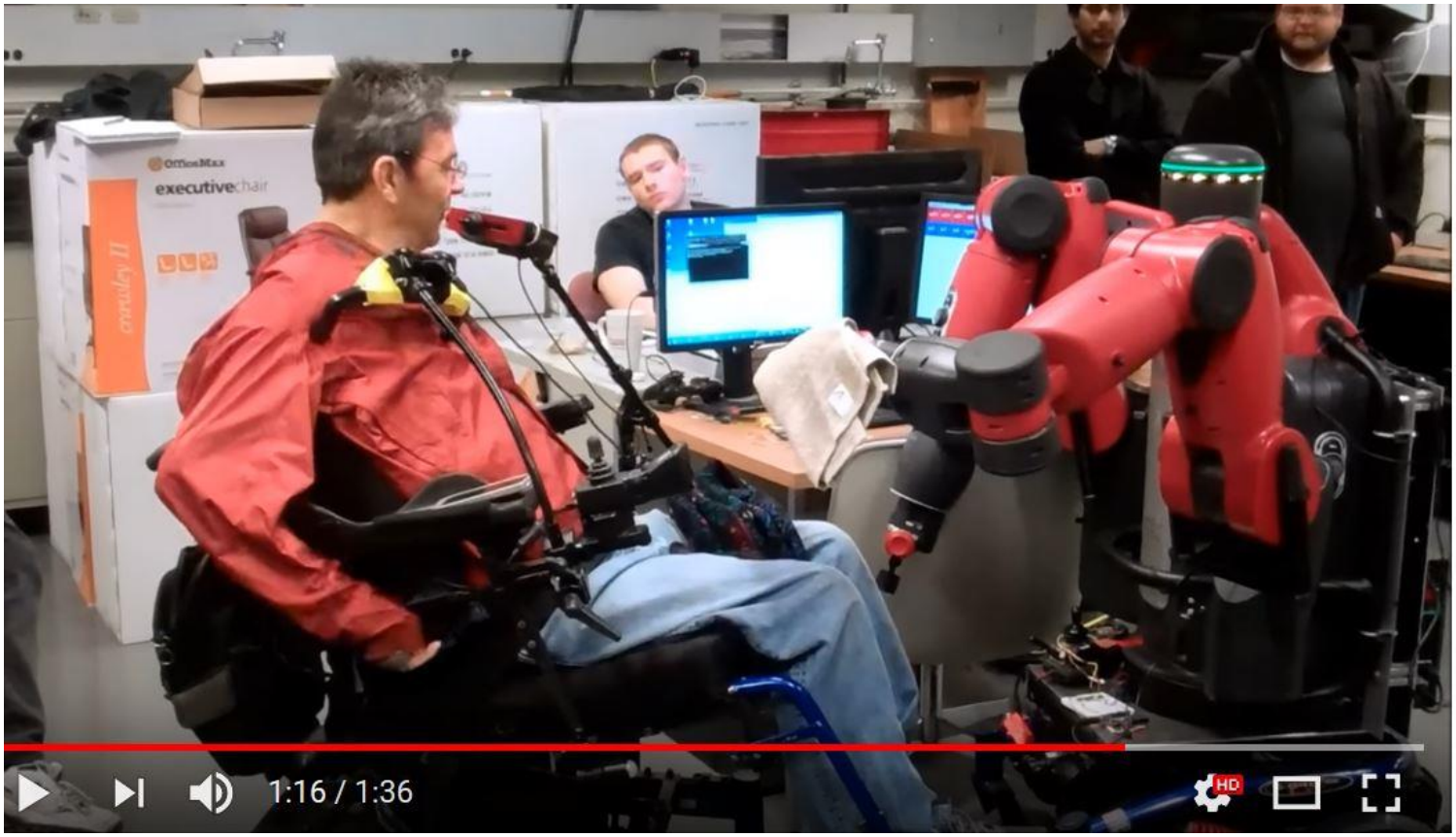

# FAST AND ACCURATE LAB WORK

Pepper Guides you

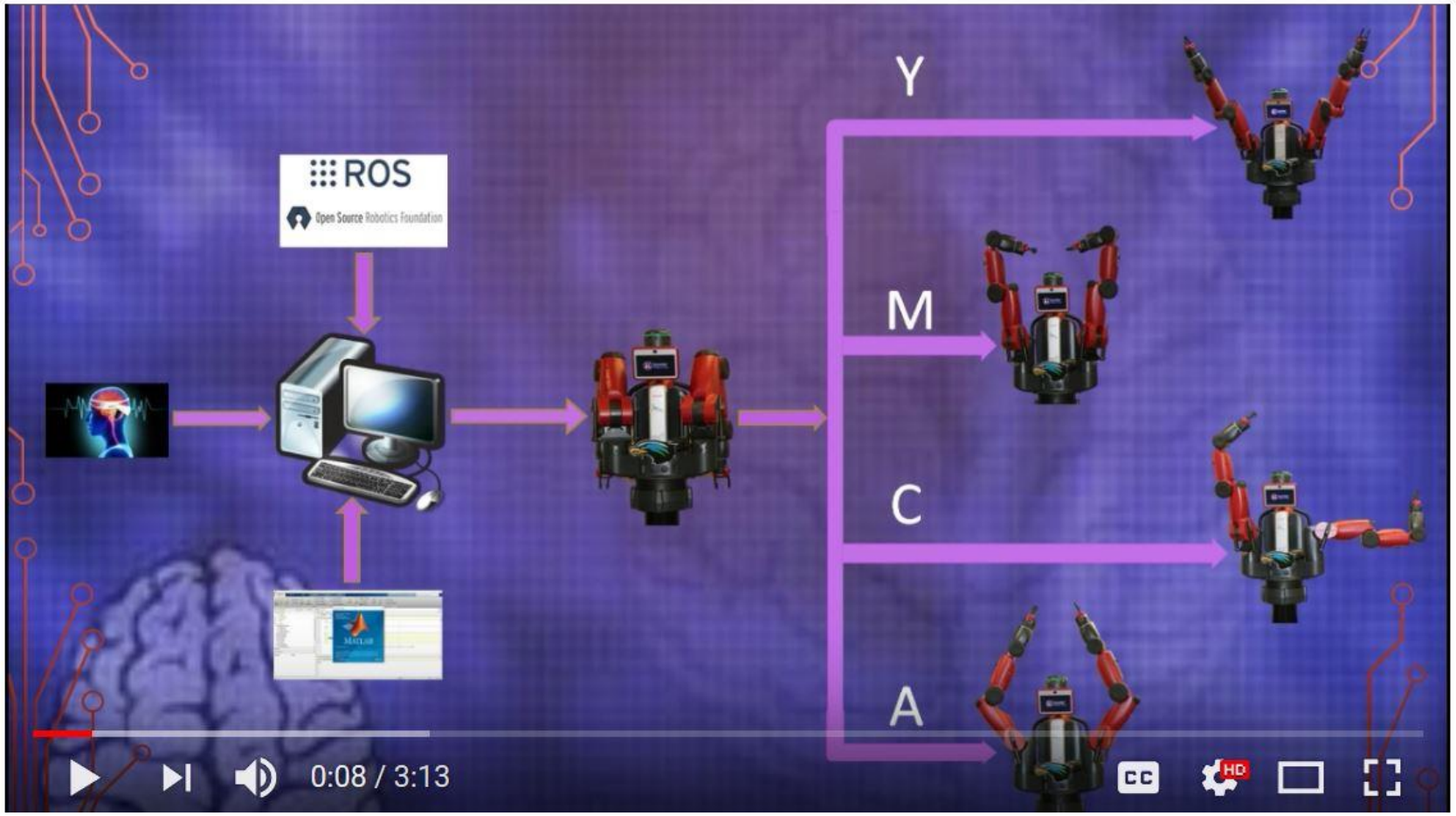

https://www.medicaldevice-network.com/comment/what-are-the-main-types-of-robots-used-in-healthcare/

https://www.youtube.com/watch?v=IVF8OrMXr3s

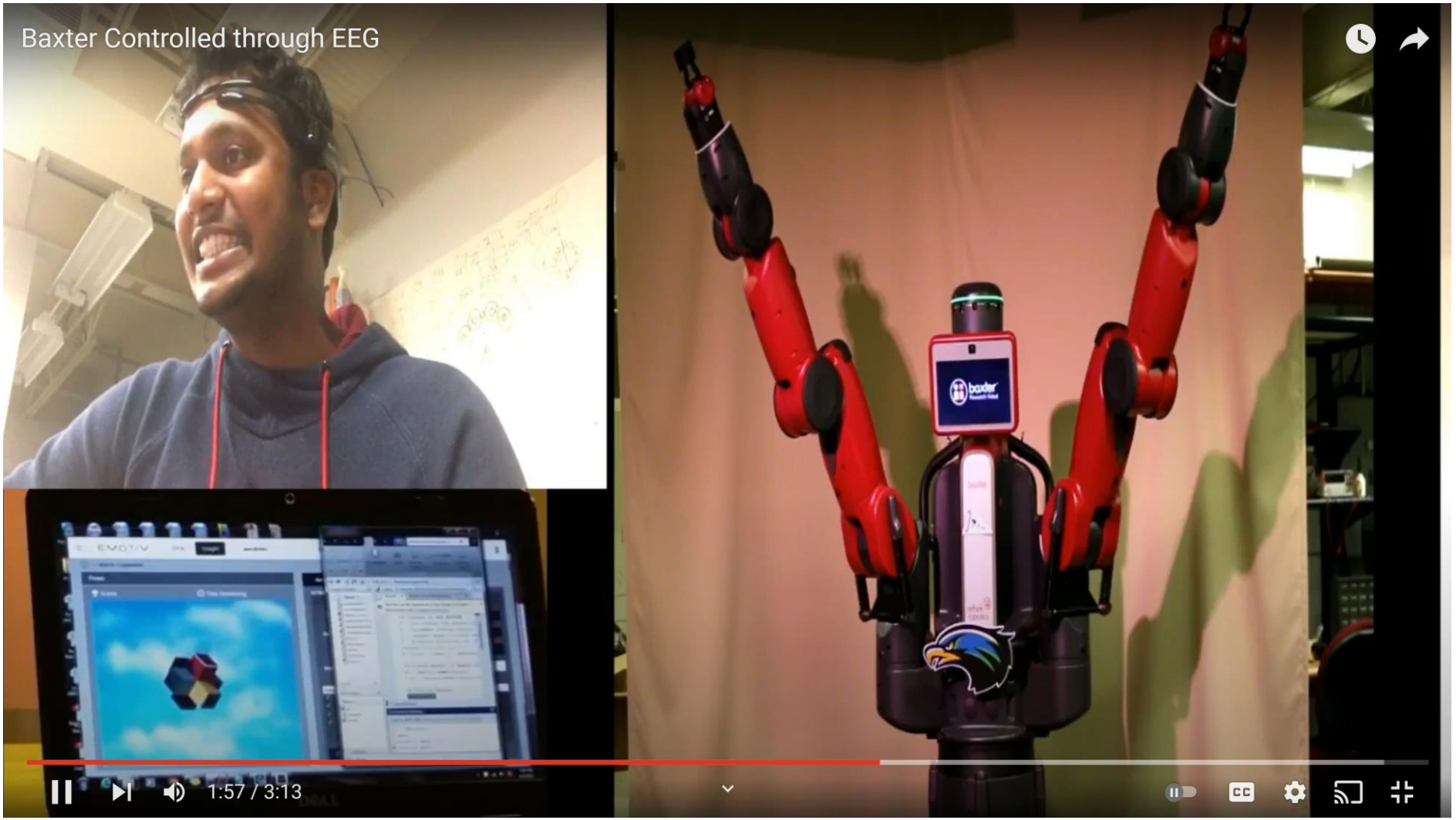
David Whalen using Jammster for the first time! Work done at the CATS laboratory at Rensselaer Polytechnic Institute.



https://www.youtube.com/watch?v=RSYHQQoSIR8




Baxter's Lab UHCL


Baxter Controlled through EEG
1:57 / 3:13


Watson for Oncology combines leading oncologists' deep expertise in cancer care with the speed of IBM Watson to help clinicians as they consider individualized cancer treatments for their patients.

Ali Unwala – Project Discontinued.

# PROSTHETIC DEVICES

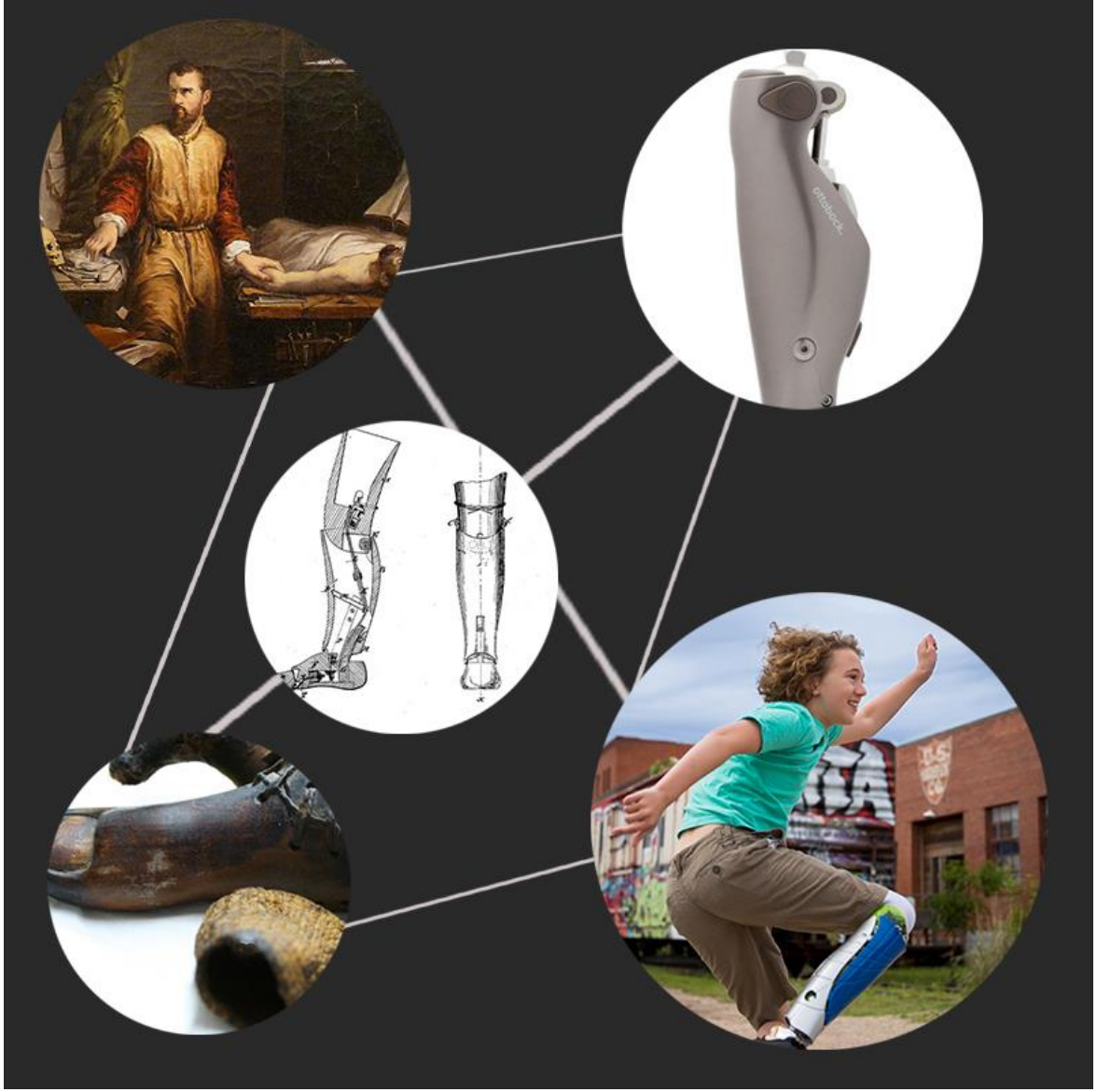
1268 **Earliest recorded mention of eyeglasses**

Roger Bacon made the first recorded comment on the use of lenses for optical purposes. However, by that time reading glasses made out of transparent quartz or beryl were already in use in both China and Europe.

1665 **Robert Hooke calls for augmented senses**

Micrographia preface 1665: "The next care to be taken, in respect of the Senses, is a supplying of their infirmities with Instruments, and as it were, the adding of artificial Organs to the natural... and as Glasses have highly promoted our seeing, so 'tis not improbable, **but that there may be found many mechanical inventions to improve our other senses of hearing, smelling, tasting, and touching."**

From “A History of Wearable Computers”



**The History of Prosthetics**

Orthotics & Prosthetics | September 21, 2015 | John Marshall

# ARTIFICIAL LIMBS

# DIGITALLY CONTROLLED LEG

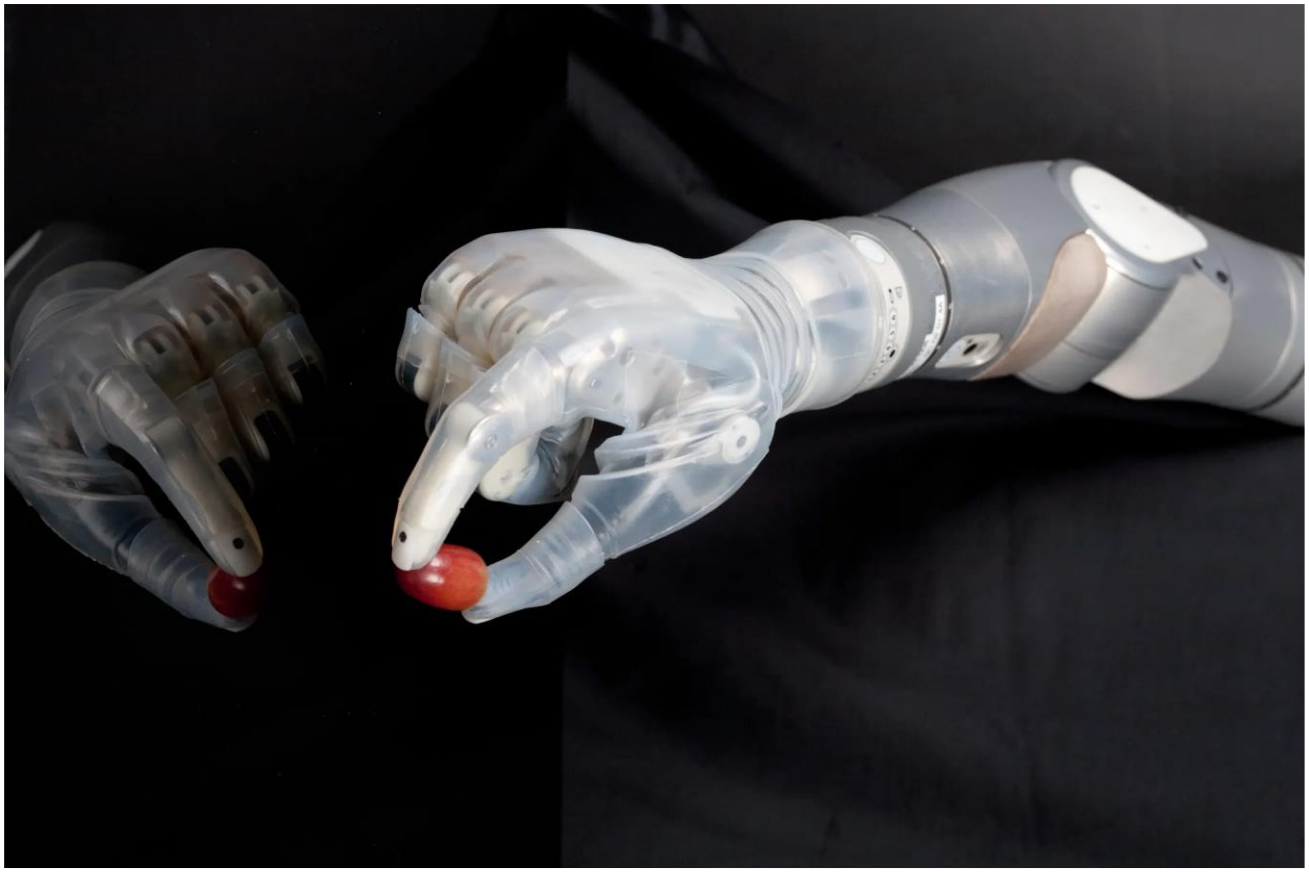
SANDIA LABS

In order to simulate a real leg's action when walking uphill, downhill or across uneven terrain, scientists plan to install a microprocessor-controlled module in the leg that will respond to signals from sensors placed along the foot and leg.

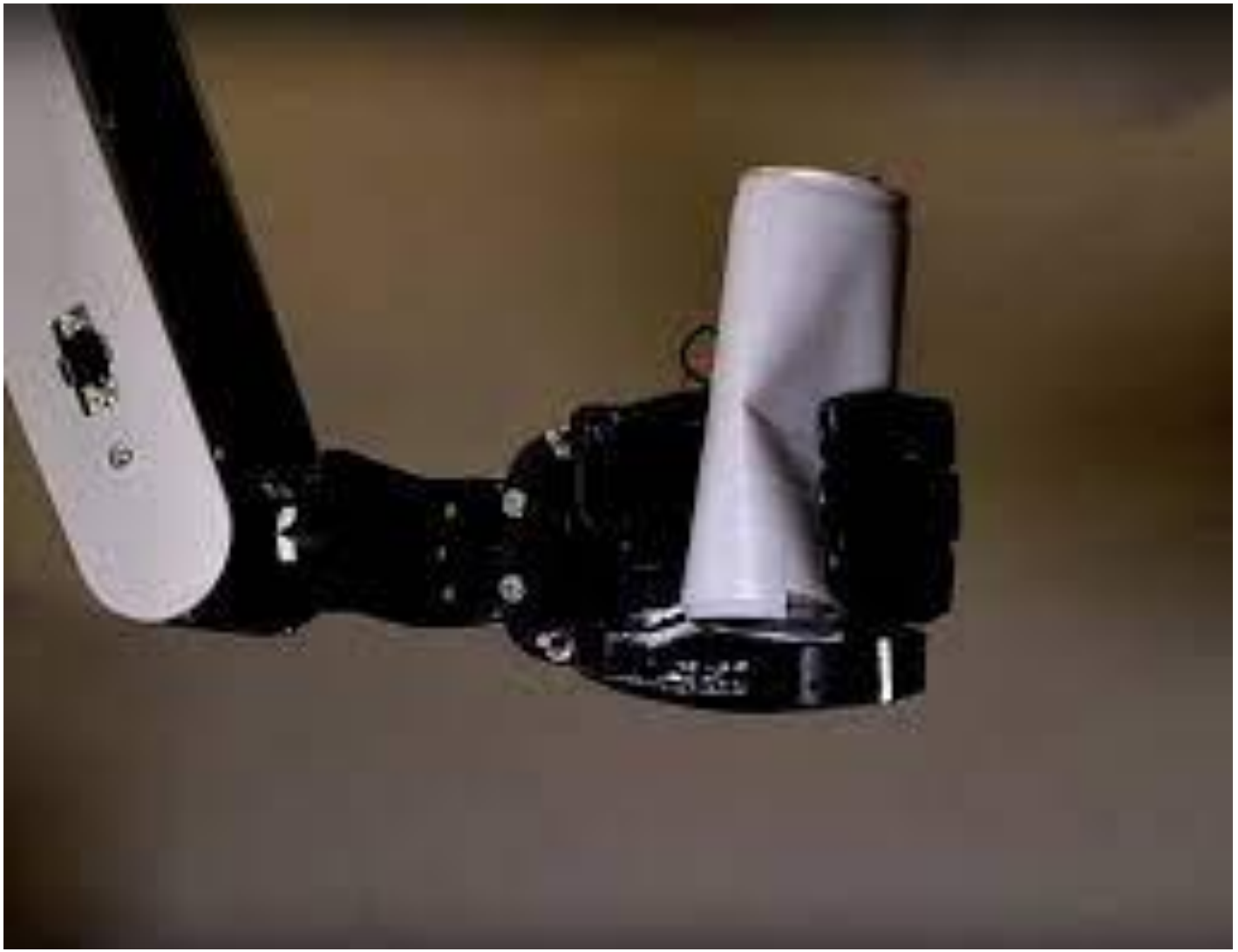
# Give Us a Hand

Dean Kamen Segway inventor develops neurally controlled arm.

The Food and Drug Administration (FDA) has approved a robotic arm intended to restore function to people with upper extremity amputations. The DEKA Arm System, dubbed “Luke” for Luke Skywalker by its inventors, is the first prosthetic arm that can perform multiple, simultaneous movements that are controlled by electrical signals sent from the patient’s muscles.

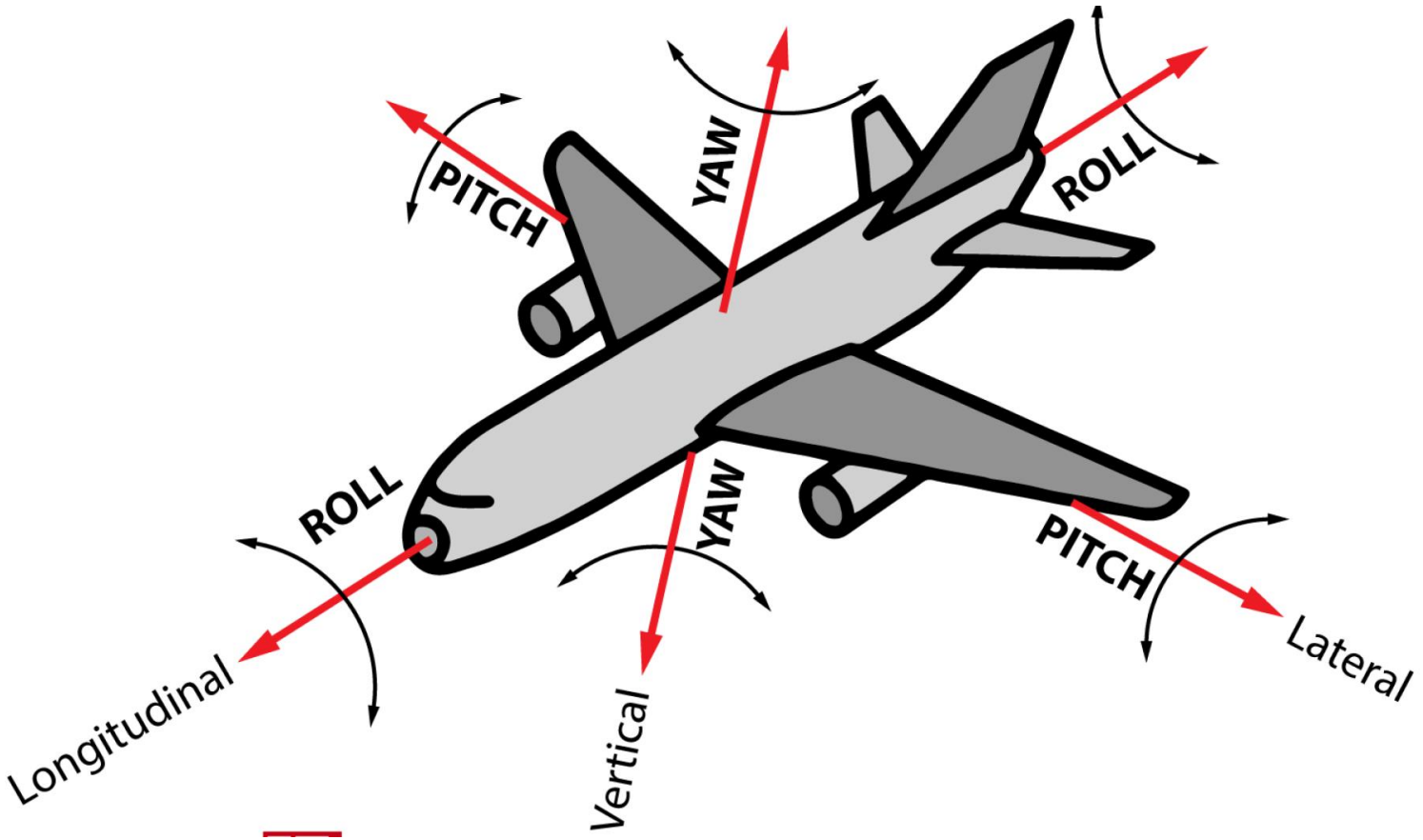


# TOO STRONG FOR ITS OWN GOOD!



THIS IS FAMILIAR TO ME!

# How Do Things Move in Space

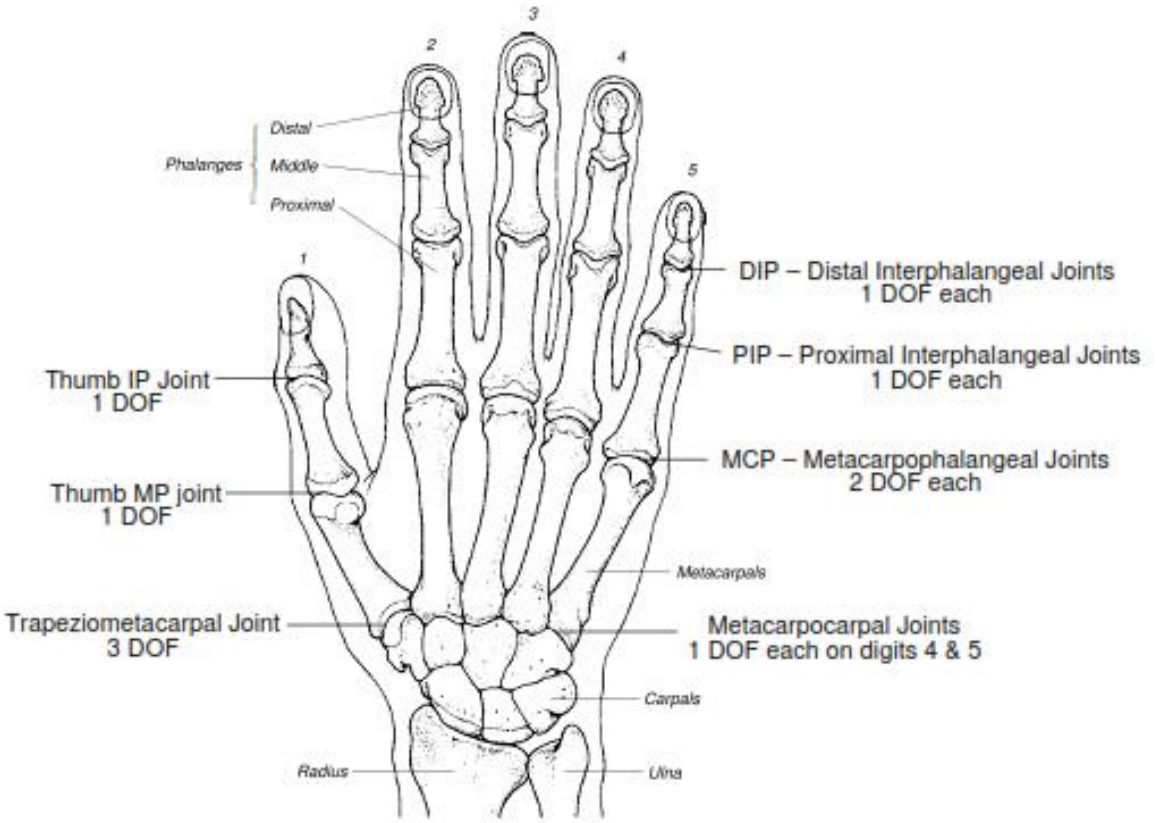



# 6 Degrees Of Freedom for a plane

The SC DEKA Arm has **10** powered degrees of freedom

https://www.wevolver.com/wevolver.staff/deka.bionic.arm.

HUMAN
27 DOF



http://www.dgp.toronto.edu/~gelkoura/handrix/paper.html

## 3. Hand Model

The human hand has 27 degrees of freedom: 4 in each finger, 3 for extension and flexion and one for abduction and adduction; the thumb is more complicated and has 5 DOF, leaving 6 DOF for the rotation and translation of the wrist [1].

**Robonaut 14 DOF Hands**

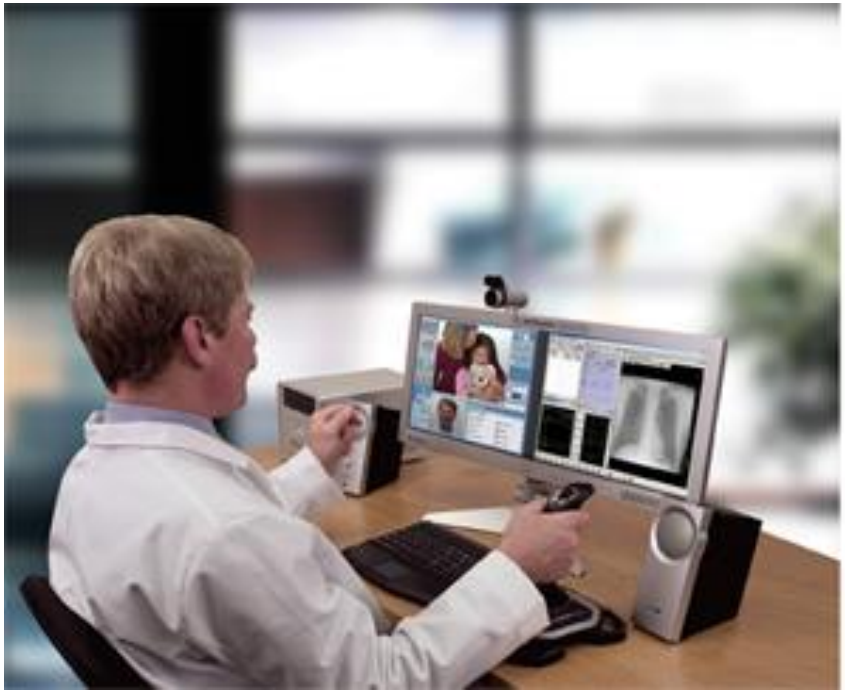
# REMOTE SURGERY
## AND
# TELECOMMUNICATION

- Gall Bladder Surgery Across the Ocean
- “Dr. Robot will see you now”
- Wearable Sensors for Monitoring Health
- Technical Considerations
- Doc at a Distance – Trama Pod

# Lindberg Operation Patient in Strasbourg (Doctors in New York)

September 7, 2001

# Dr. Robot will see you now!

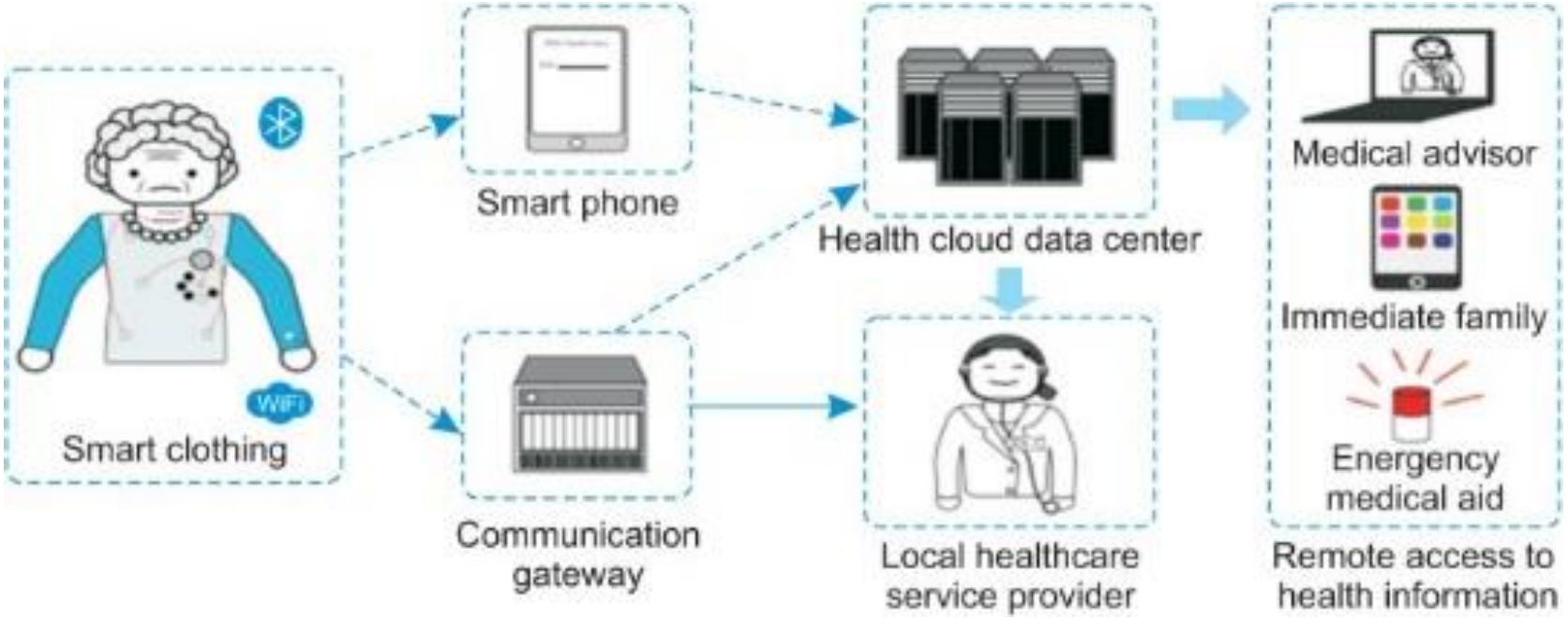


Remote communication, examination and record keeping


For the Patient

For the Doctors


10:09
00:00.00

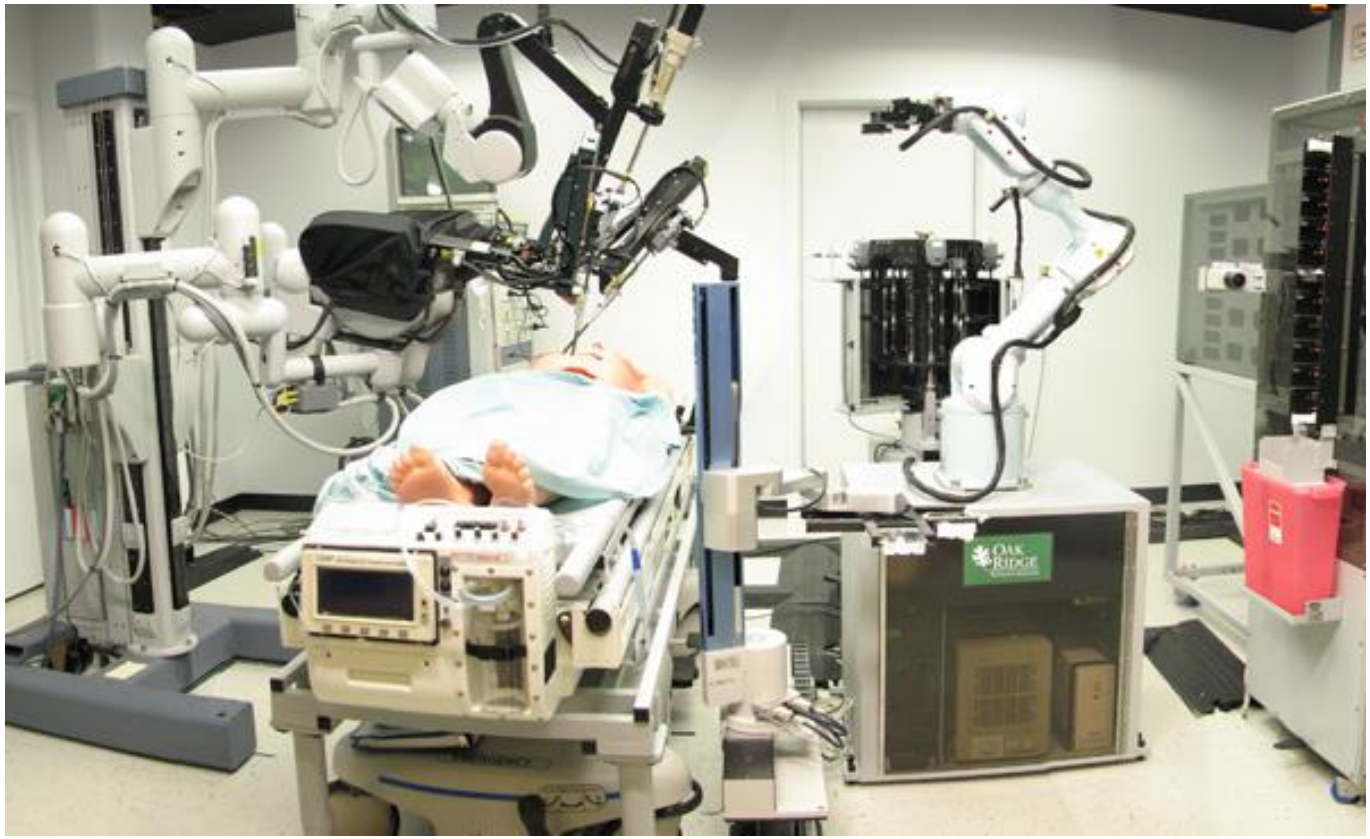

Smart clothing
WiFi
Smart phone
Communication gateway
Health cloud data center
Local healthcare service provider
Medical advisor
Immediate family
Energency medical aid
Remote access to health information

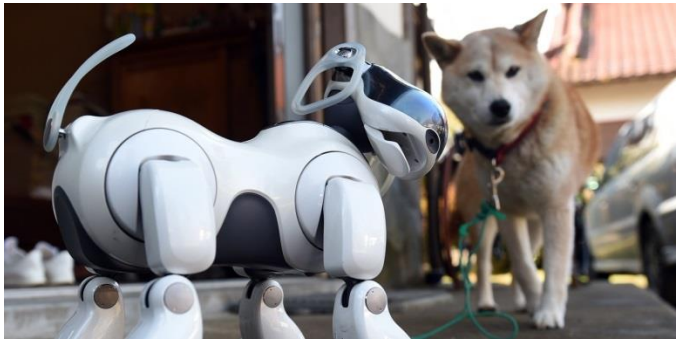
# Doc at a Distance

- DARPA has funded a number of projects to create remotely operated surgery units
- The surgical robot would be controlled by a doctor at some remote location
- Trauma Pod is a prototype example

# TRAMA POD

https://www.sri.com/case-study/from-the-home-front-to-the-battlefield-providing-access-to-lifesaving-care/


OAK
RIDGE



# SOCIAL ROBOTS


PRESENT AND FUTURE

TOM HARMAN LIFE MEMBER IEEE

IEEE
Advancing Technology for Humanity

# CHARACTERISTICS OF SOCIAL ROBOTS

A **social robot** is an autonomous robot that interacts and communicates with humans or other autonomous physical agents by following social behaviors and rules attached to its role. This definition suggests that a social robot must have a physical embodiment .

Some definitions include robots that illicit or display emotions.

I extend the definition somewhat to include robots to aid humans in various ways including in the workplace. The main point is that he robots cooperate with humans to accomplish their tasks.

In any case, cost, safety, and ease of use are important characteristics.

# PEPPER

Pepper is the first humanoid robot capable of recognising the principal human emotions and adapting his behavior to the mood of his interlocutor.

Your robot **evolves with you**. Pepper gradually memorizes your **personality** traits, your **preferences**, and adapts himself to your **tastes** and **habits**.


Nestlé is planning on equipping more than 1,000 Nescafé sales outlets in Japan to inform their customers about their different products in a fun way thanks to Pepper.

SoftBank has reportedly sold more than 7,000 Peppers. It's not cheap. The 64-pound robot costs **about $1,700** upfront and an additional **$134 a month** for 36 months for maintenance and $89 a month for 36 months for insurance.


Room-service robot called Relay

# STARSHIP – YOUR PIZZA IS COMING

# CLEAN


ROOMBA  with Localization

# CHAUFFEUR

**Watch out college professors, the robots are coming for your jobs**

# RESEARCH

- TREATMENT - UHCL Example
- MINIATURE MOTOR for Precise Control
- RICE UNIVERSITY
- NASA
- UH – Aaron Becker

# Early Work in Bioengineering

- J. W. Clark, E. C. Greco and T. L. Harman, "Experience with a Fourier Method for Determining the Extracellular Potential Fields of Excitable Cells with Cylindrical Geometry," Critical Reviews in Bioengineering, CRC Press, Inc., 1978

UHCL

# Robot Control from Sequential Image Planes of a 3D Object

*S. B. Premkumar, T. L. Harman, A. G. Houston*
University of Houston-Clear Lake, Houston, TX

*L. A. Nguyen*
Lockheed Engineering and Sciences Co., Houston, TX

July 15, 1993
SPIE International Symposium on Optics, Imaging and Instrumentation.
San Diego, CA

# *Image Coordinates*

- TRUS image data of sequencial cross-sections are obtained at 2mm intervals from base to apex of the gland.

Prostate

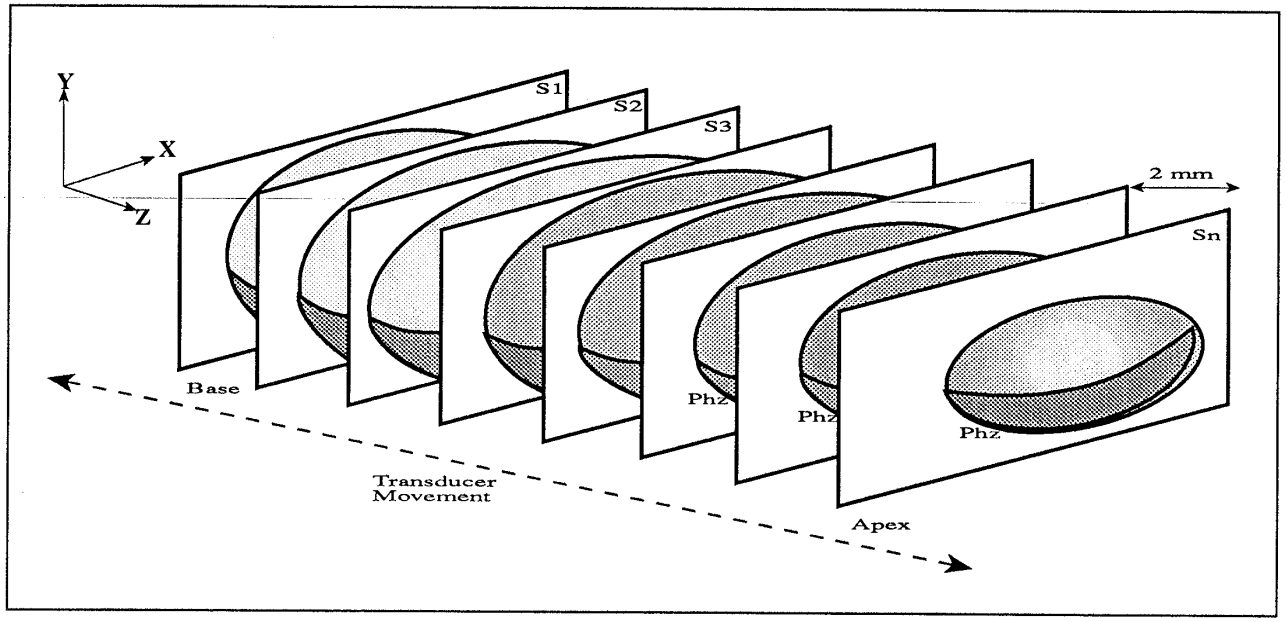



***Fig 1.*** *Sequential TRUS image planes comprise the 3D volume of the gland.*

Transrectal Ultrasound images of the prostate

# *Robot Coordinates*

- Scorbot - ER VII robot system has five degrees of freedom and is mounted on a slide base. Slide base provides additional degree of freedom.

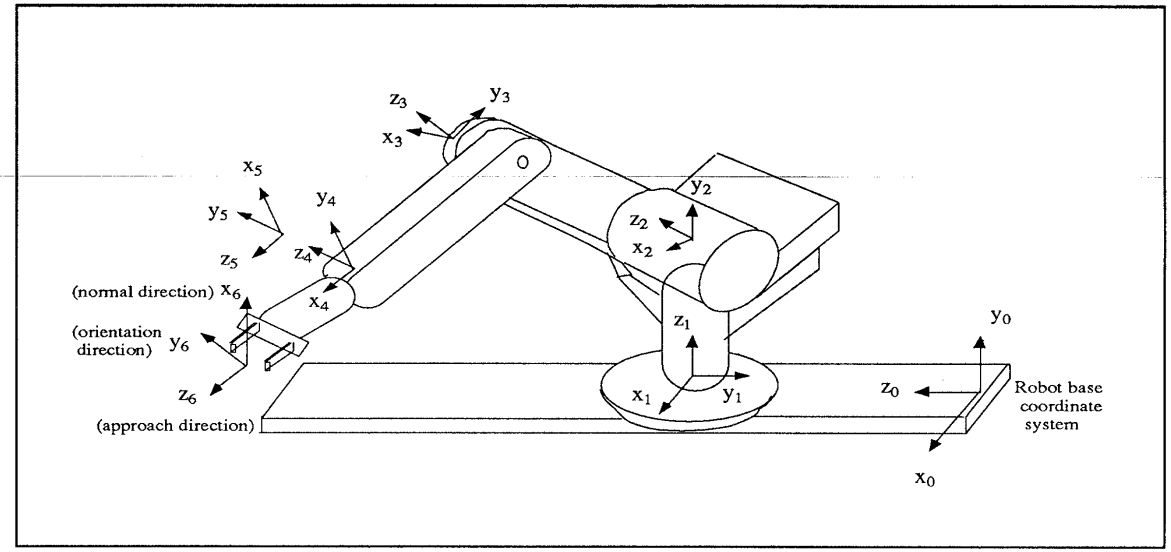
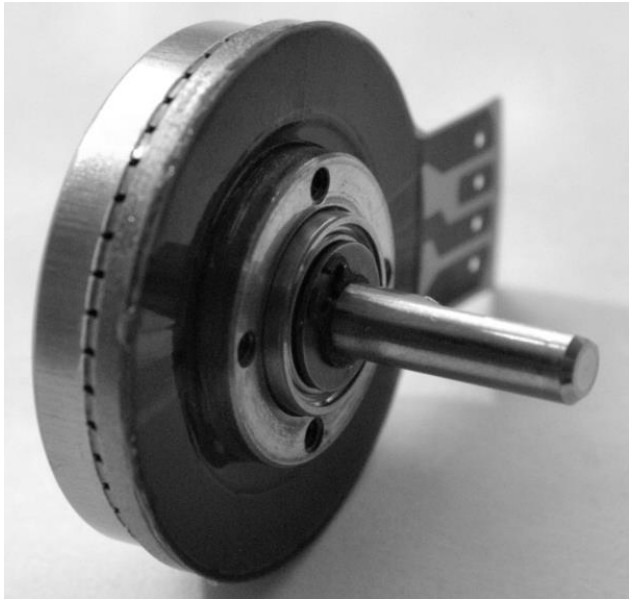



***Fig 2.*** *Scorbot - ER VII coordinates systems at various joints are shown.*

Robot System

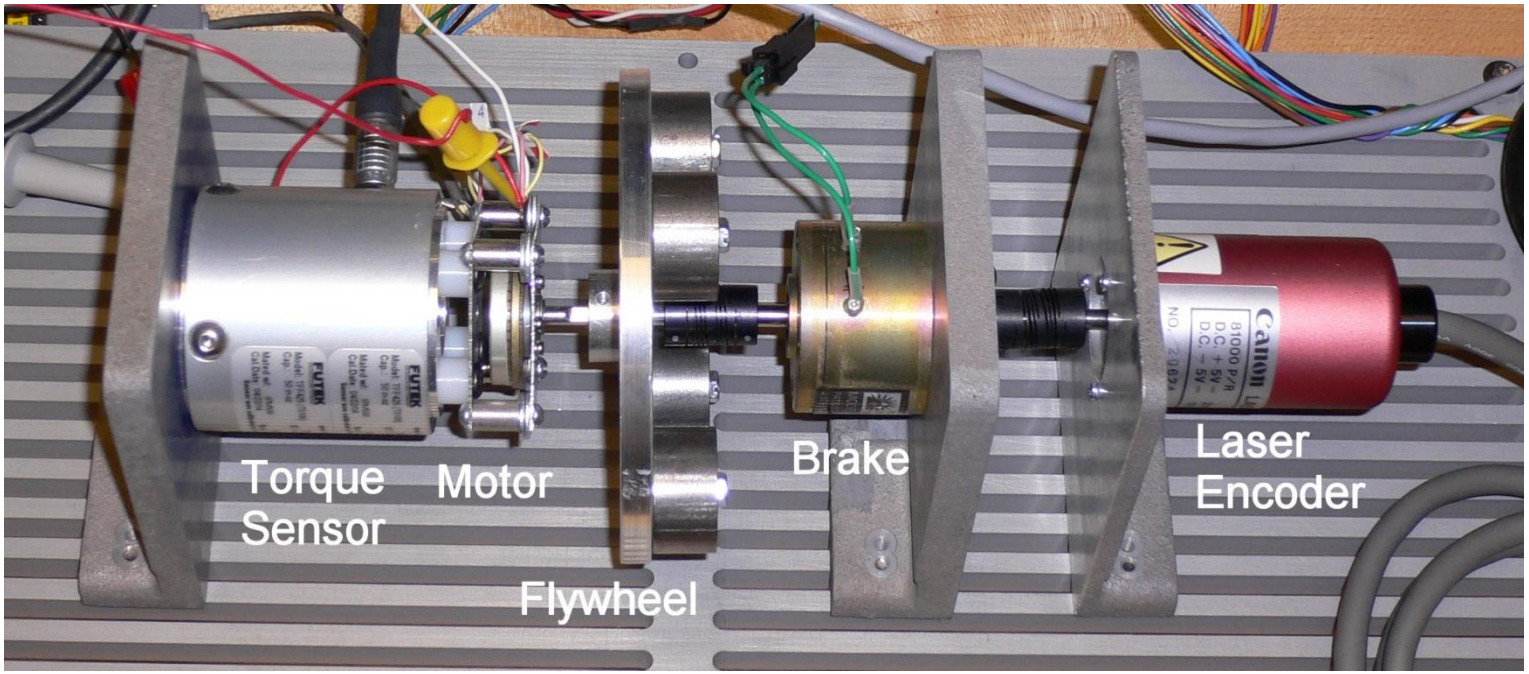


Piezoelectric Ultrasonic Motor


The powerful magnetic field generated by an MRI machine makes hazards of even small ferromagnetic objects like screws, let alone, motion devices like permanent magnet motors, gearboxes, and actuators. It was obvious from the outset that the MRI robot had to be based on non-traditional actuation. The answer proved to be a **piezoelectric device.**

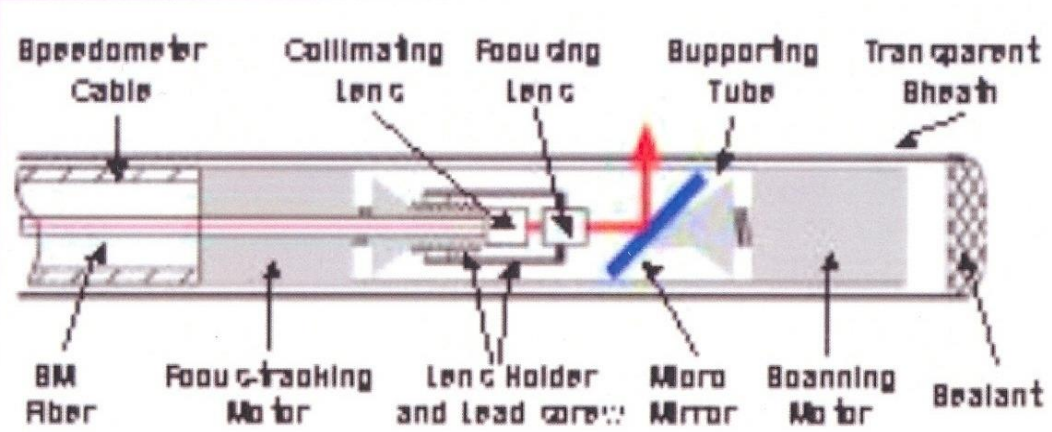
Experimental Setup to Characterize motor

Systems Laboratory in Delta Building, Dabney and Harman



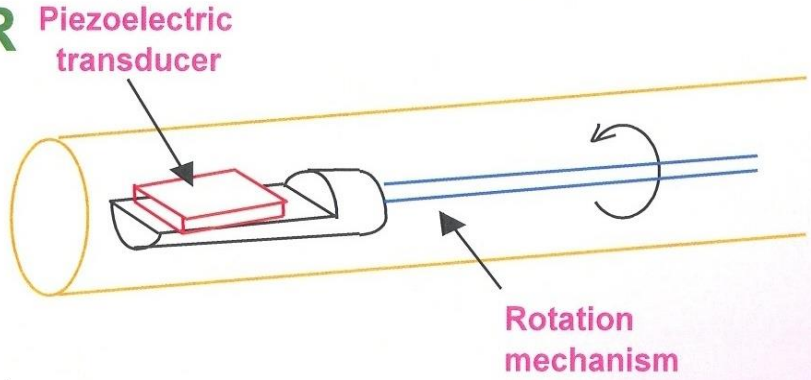
## ENDOSCOPE

Sideview Monitoring

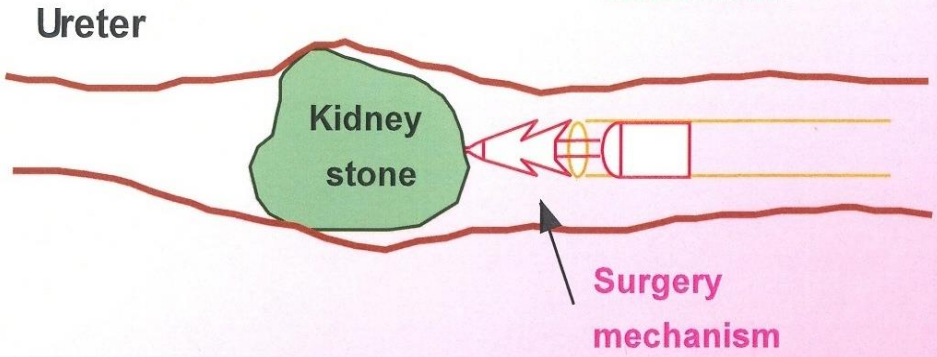



## MEDICAL CATHETER

Sideview Monitoring



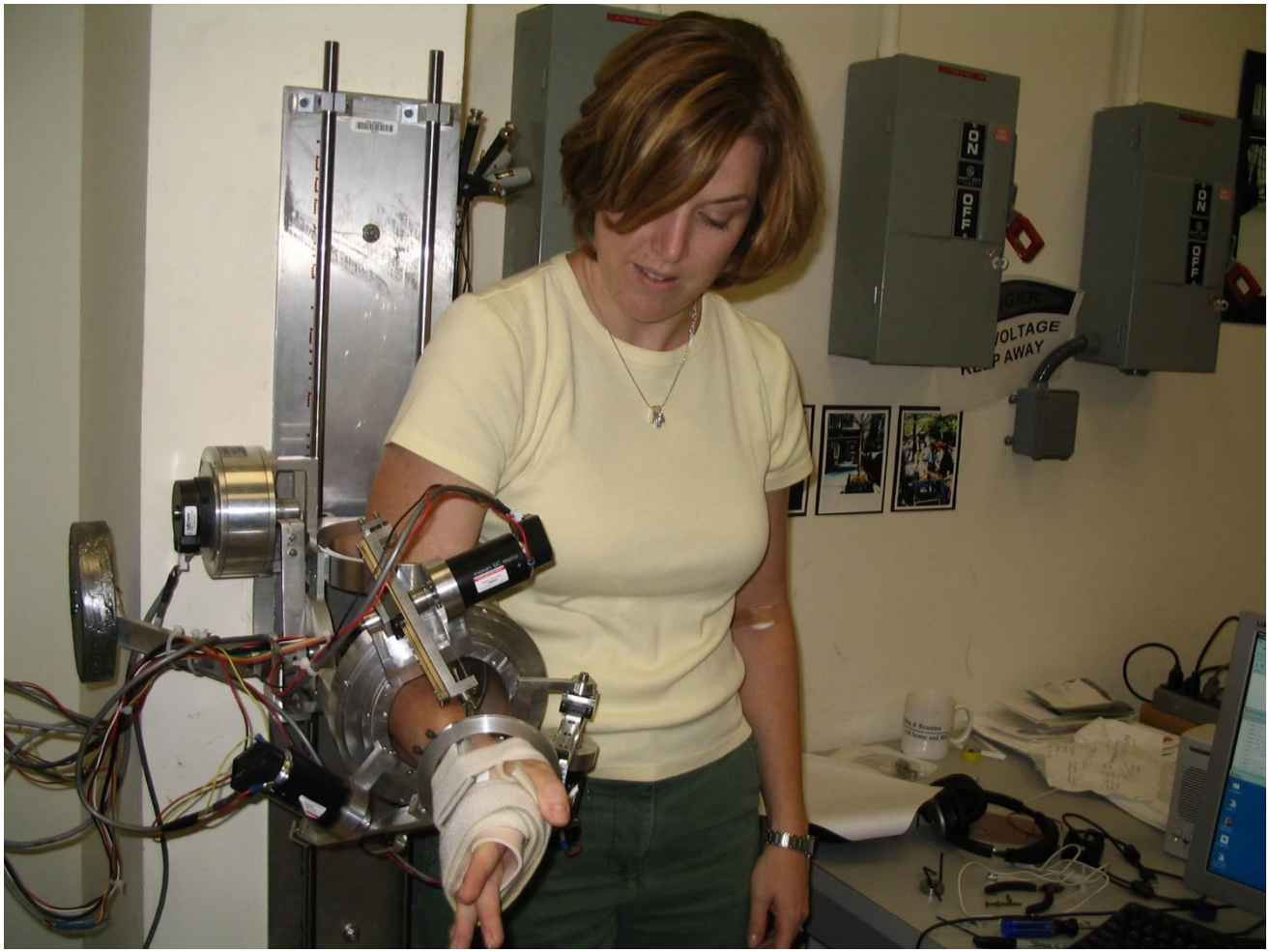

Surgery



# RICE , NASA, UH

- Dr. Marcia O'Malley - REHABILITATION
- NASA - Robonaut
- Dr. Frank Tittel – Optical Nose
- Dr. Aaron Becker UH – Magnetic Control of nano-robots

# ARM EXOSKELETON

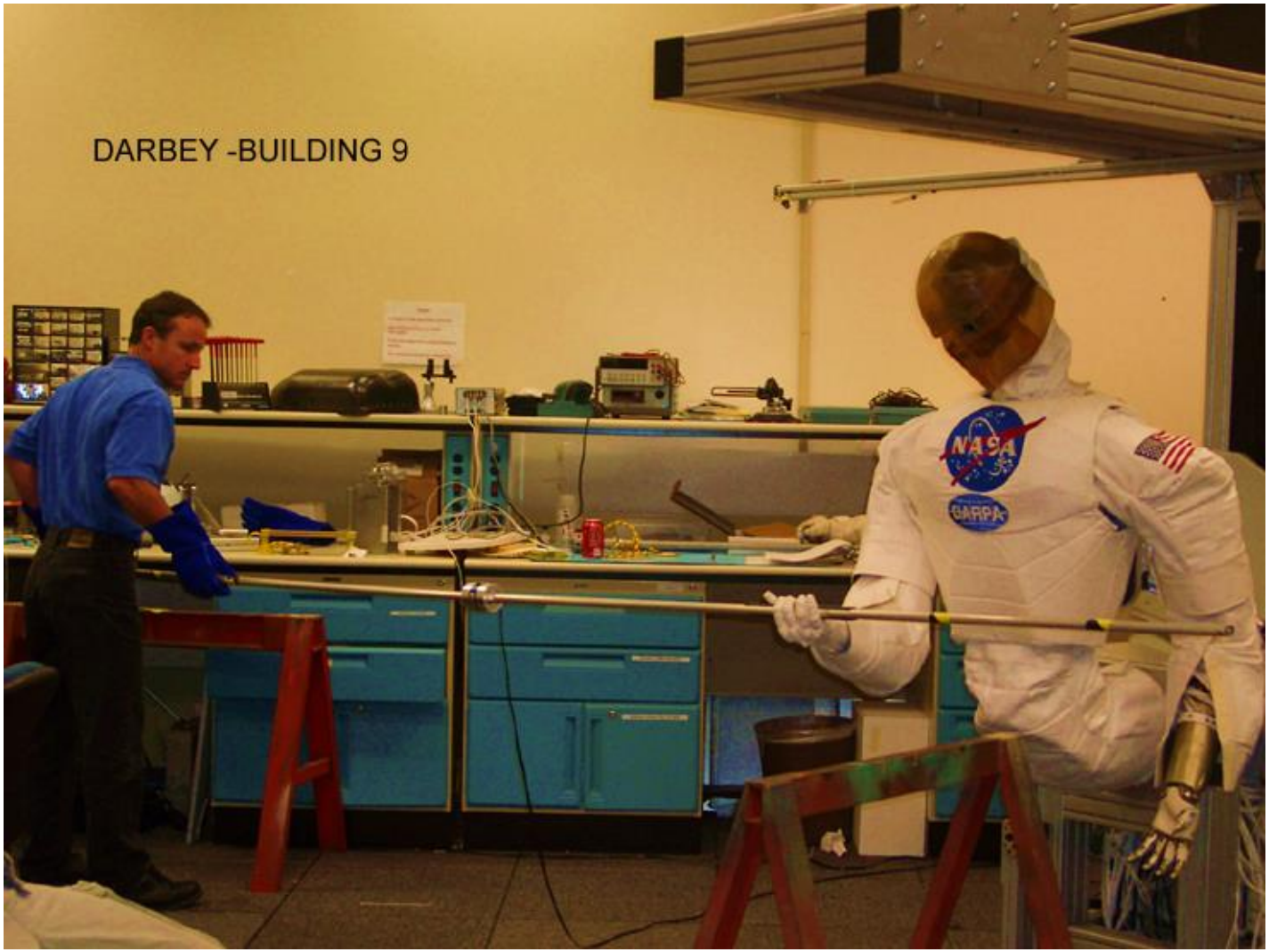


# HAPTIC FEEDBACK

# STROKE REHABILITATION

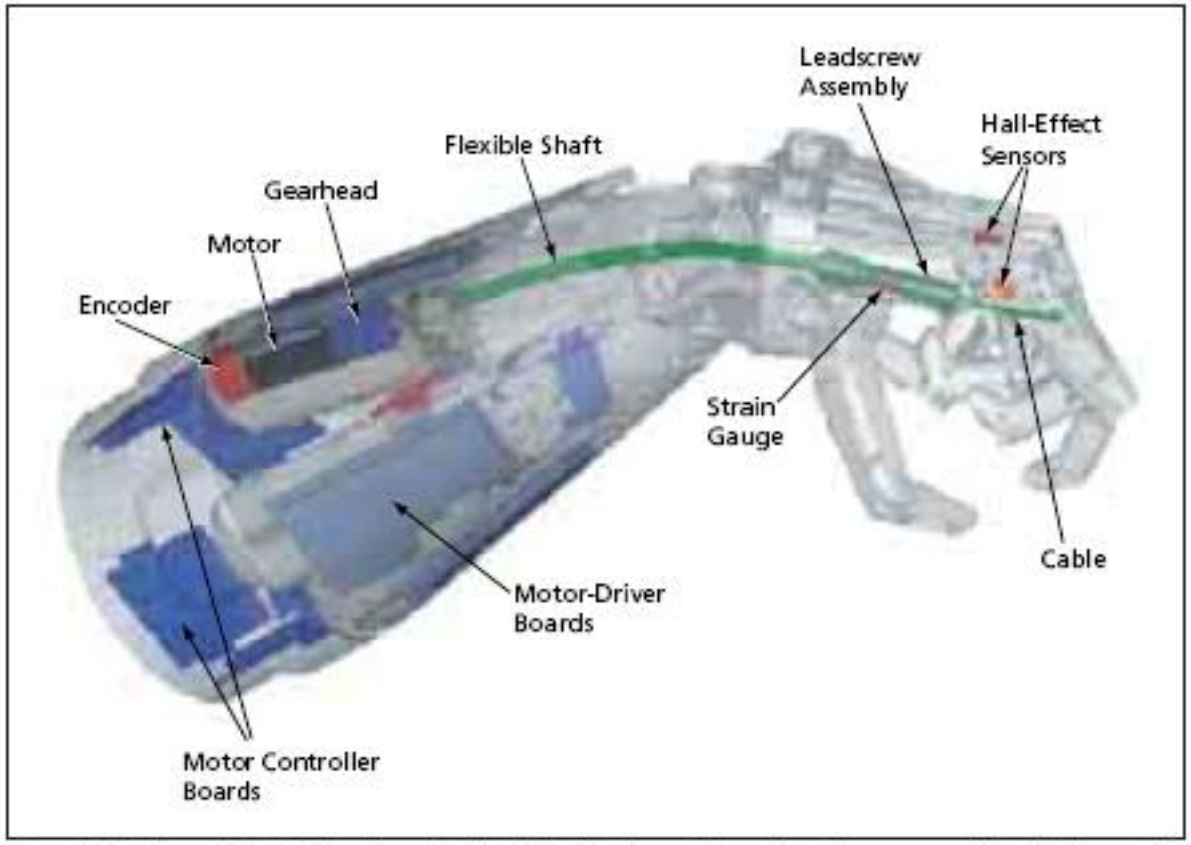
## Mirror Image Movement Enabler

# ROBONAUT JSC



# ROBONAUT WITH BALL

# ROBOT FOREARM JSC



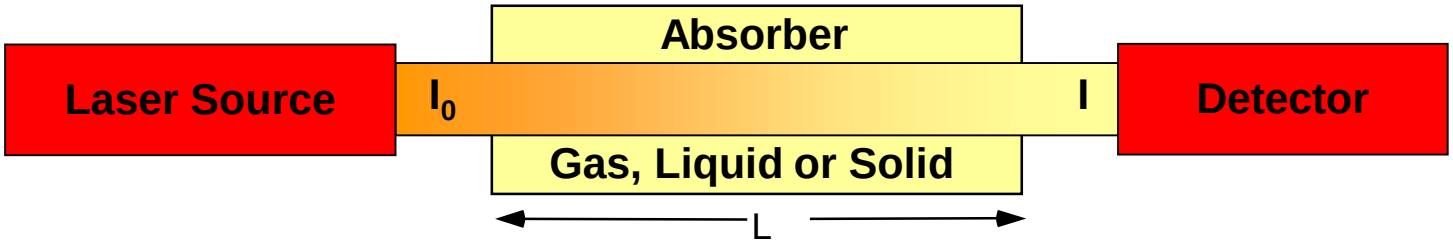

**One of the Finger Drive Trains** is emphasized in this view of the robot forearm and hand. The motive forces for the fingers are generated in the forearm and are transmitted to the fingers by flexible shafts, leadscrews, and cables.

# OPTICAL NOSE?

## Development of Quantum-Cascade Laser Based Biosensor Technology

**Thomas L. Harman [UHCL] / Frank K. Tittel [Rice U] / John C. Graf [NASA-JSC] / Yury Bakhirkin [UHCL]**

# Direct Laser Absorption Spectroscopy



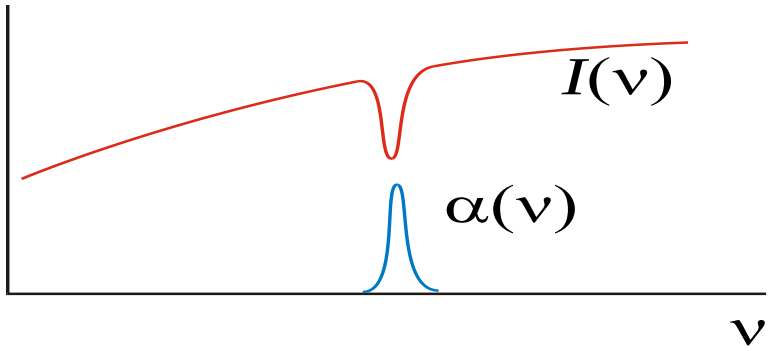

**Beer-Lambert's Law of Linear Absorption**

$$I(\nu) = I_0 \cdot e^{-\alpha(\nu) \cdot P_a L}$$

$\alpha(\nu)$ - absorption coefficient [$cm^{-1}$ $atm^{-1}$]; L – path length [cm]

$\nu$ - frequency [$cm^{-1}$]; $P_a$- partial pressure [atm]

$$\alpha(\nu) = C \cdot S(T) \cdot g(\nu - \nu_0)$$




C - total number of molecules of absorbing gas/atm/$cm^3$ [molecule·$cm^{-3}$ ·$atm^1$]

S - molecular line intensity [cm ·$molecule^{-1}$]

$g(\nu - \nu_0)$ - normalized lineshape function [cm], (Gaussian, Lorentzian, Voigt)



RICE

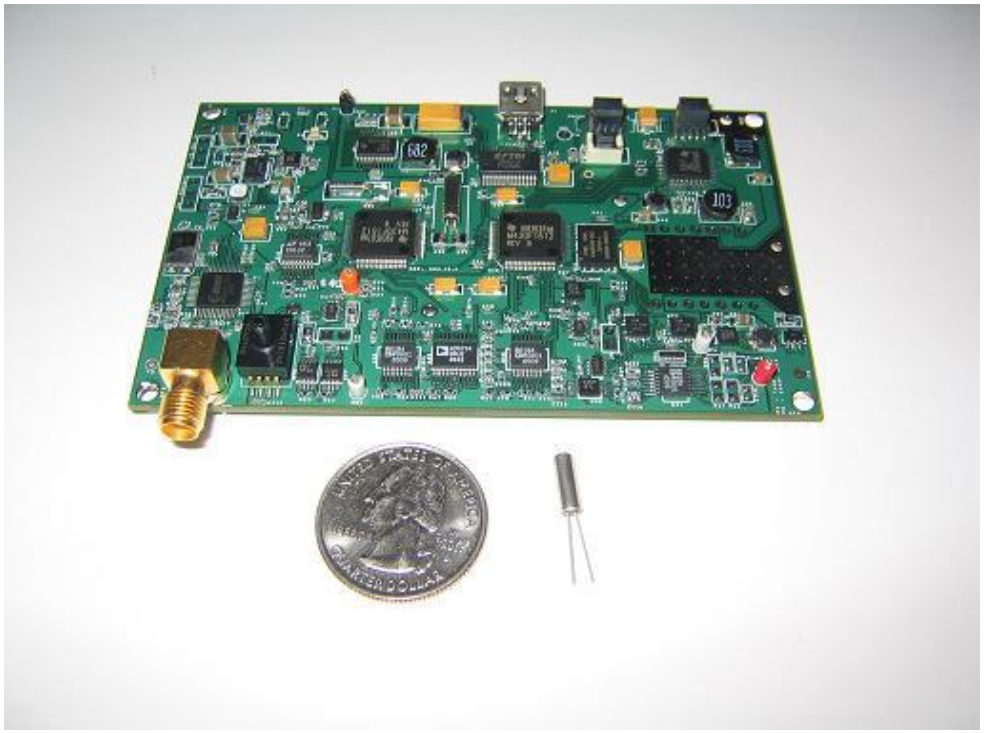
# Target Gases – 1

| Molecule | Formula | Trace Concentration in Breath (ppb) | Biological/Pathology Indication |
|---|---|---|---|
| **Nitric Oxide** | **NO** | **6 - 100** | **Inflammatory and immune responses (e.g., asthma) and vascular smooth muscle response** |
| **Carbon Monoxide** | **CO** | **400 - 3000** | **Smoking** response, CO poisoning, vascular smooth m**uscle response, platelet aggregation** |
| **Hydrogen Peroxide** | **$H_2O_2$** | **1 - 5** | **Airway Inflammation, Oxidative stress** |
| **Carbonyl Sulfide** | **OCS** | **100 – 1000** | **Liver disease and acute allograft rejection in lung transplant recipients** |
| **Formaldehyde** | **HCHO** | **400 - 1500** | Cancerous tumors, breast cancer |

RICE

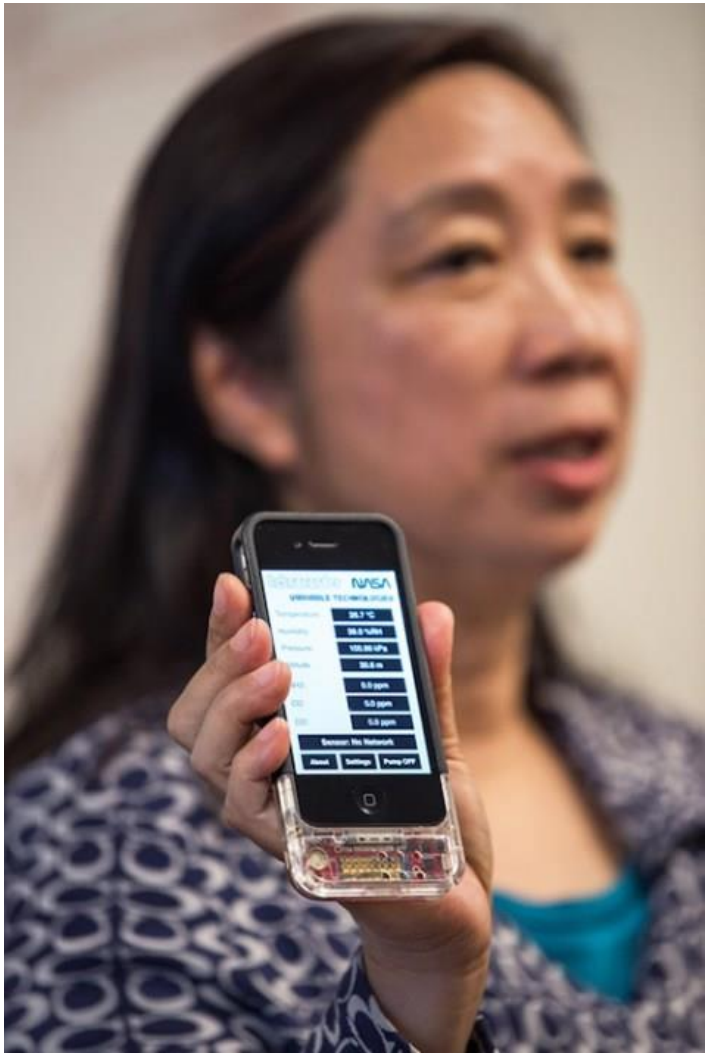
# Rice System 2002

# New Circuit Board 2008 with Stephen So



Design at Rice for handheld spectrometer

# NASA Develops the ‘E-Nose,’ a Handheld Breath Analyzer That Can Measure Multiple Biomarkers Used in Medical Laboratory Tests



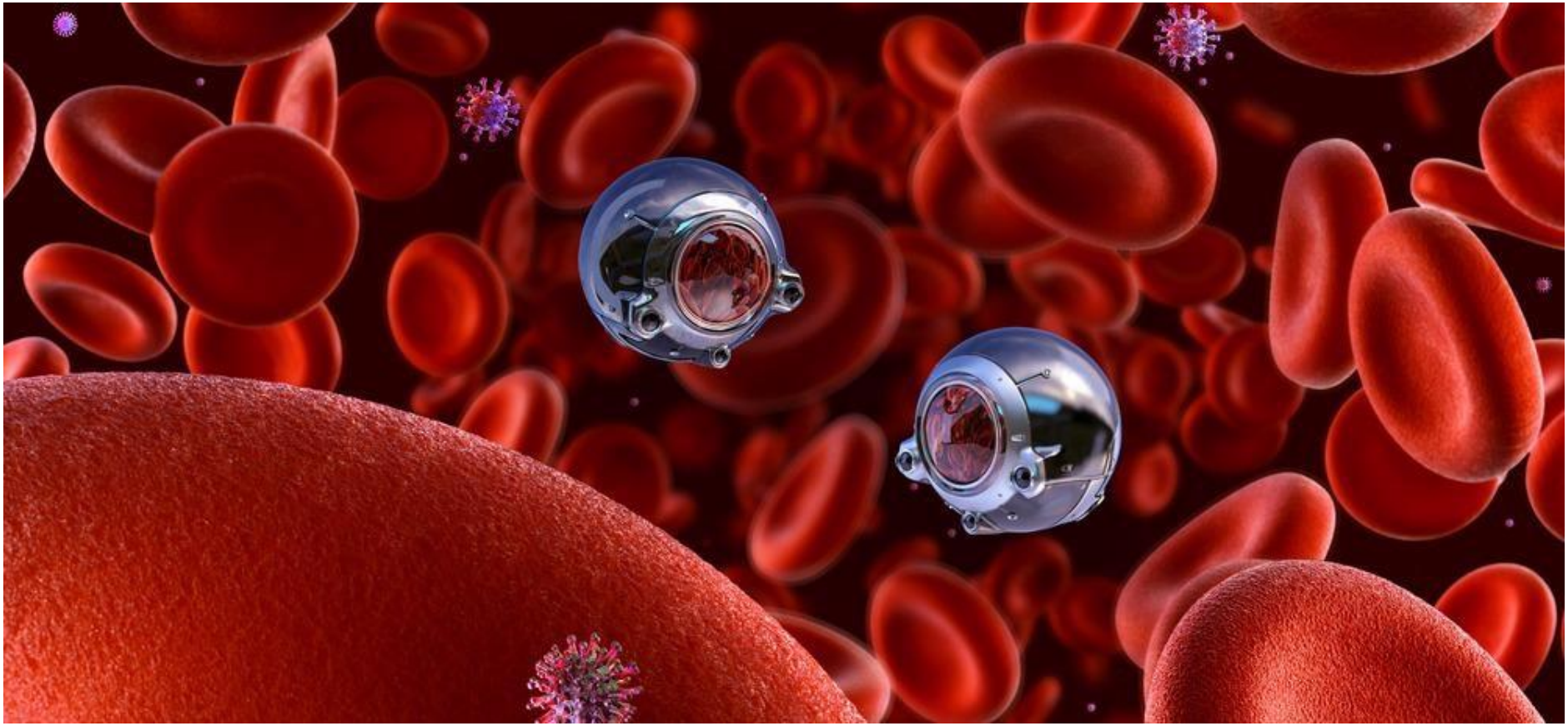

https://www.owlstonemedical.com/getting-started/

**Rice air sensors tested near Beijing's Olympic stadium**

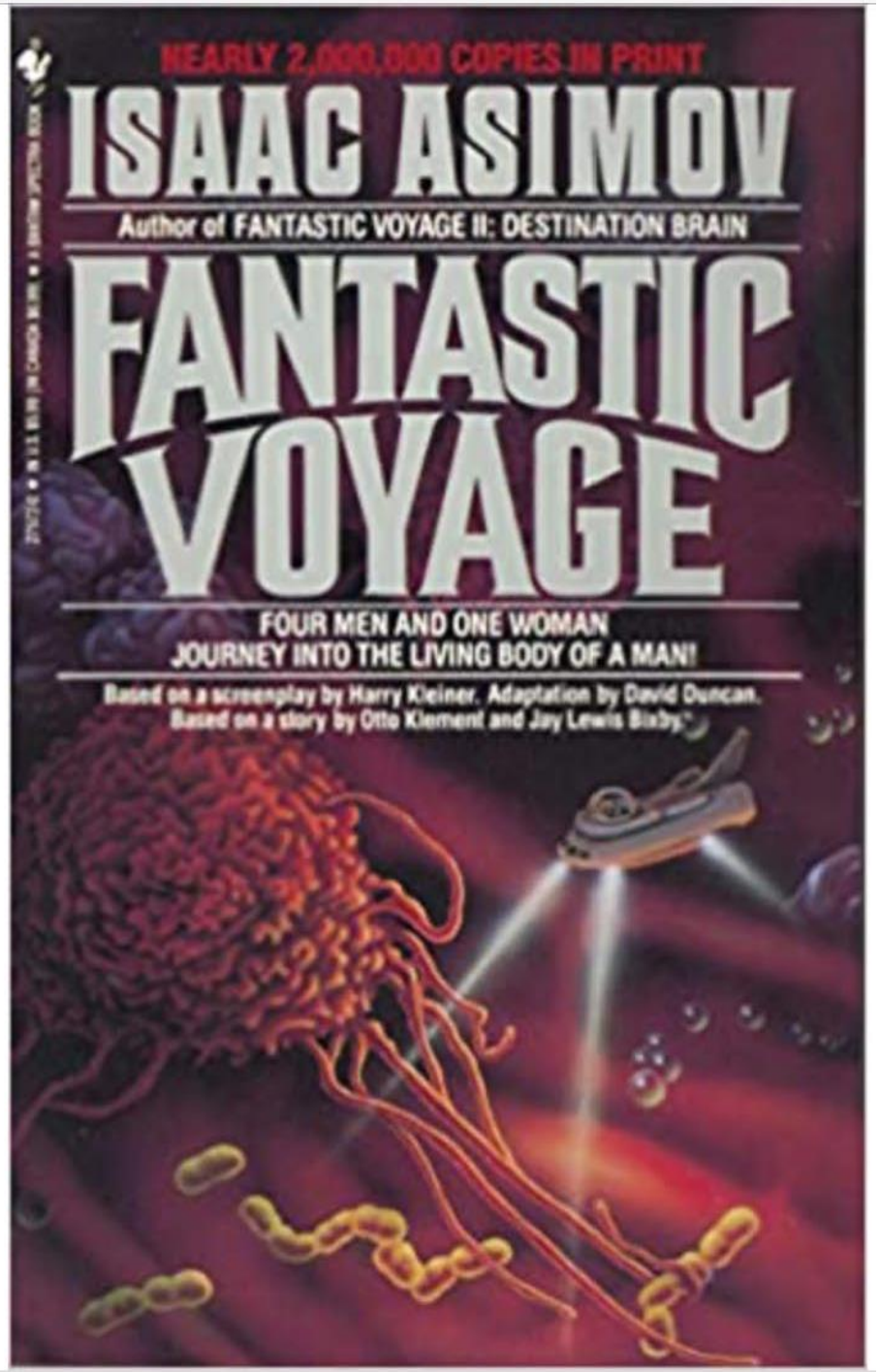
*Laser-based devices measure ozone-precursor nitric oxide*

# RICE SPECTROMETER in BEIJING

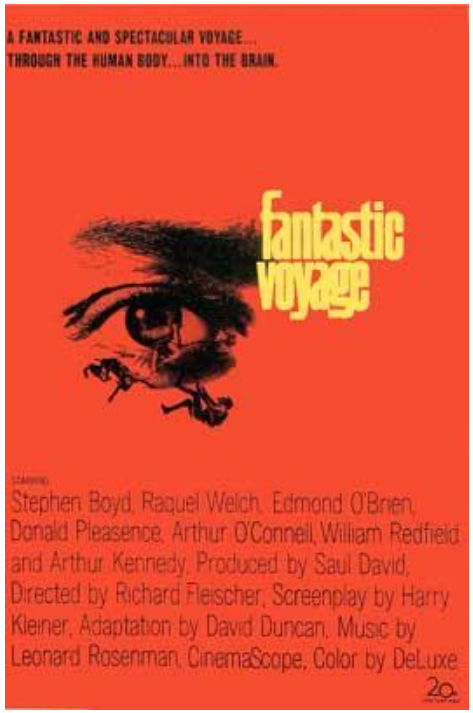
# NANOTECHNOLOGY



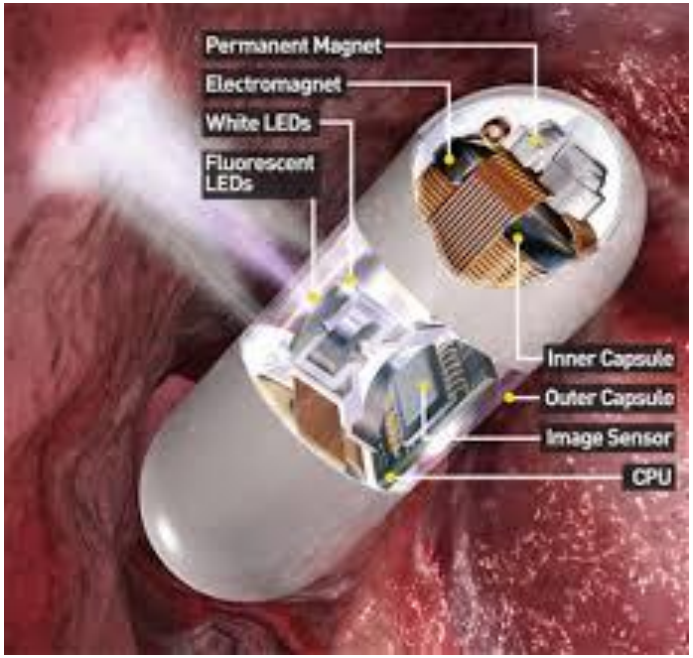
https://www.azonano.com/article.aspx?ArticleID=5761



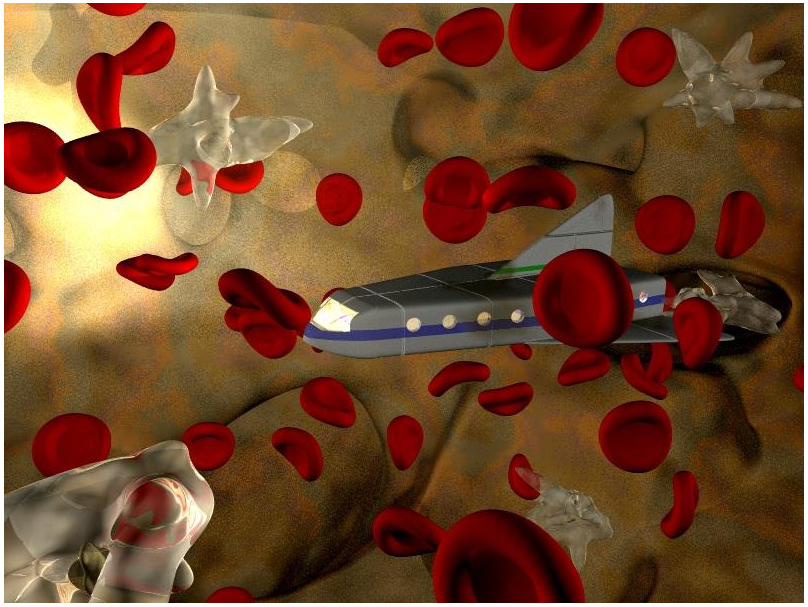

**Nanotechnology** has exploded in recent years, with research growing and the establishment of new and exciting applications that exploit the unique properties of nanoparticles, particularly in medicine, electronics, and materials science.

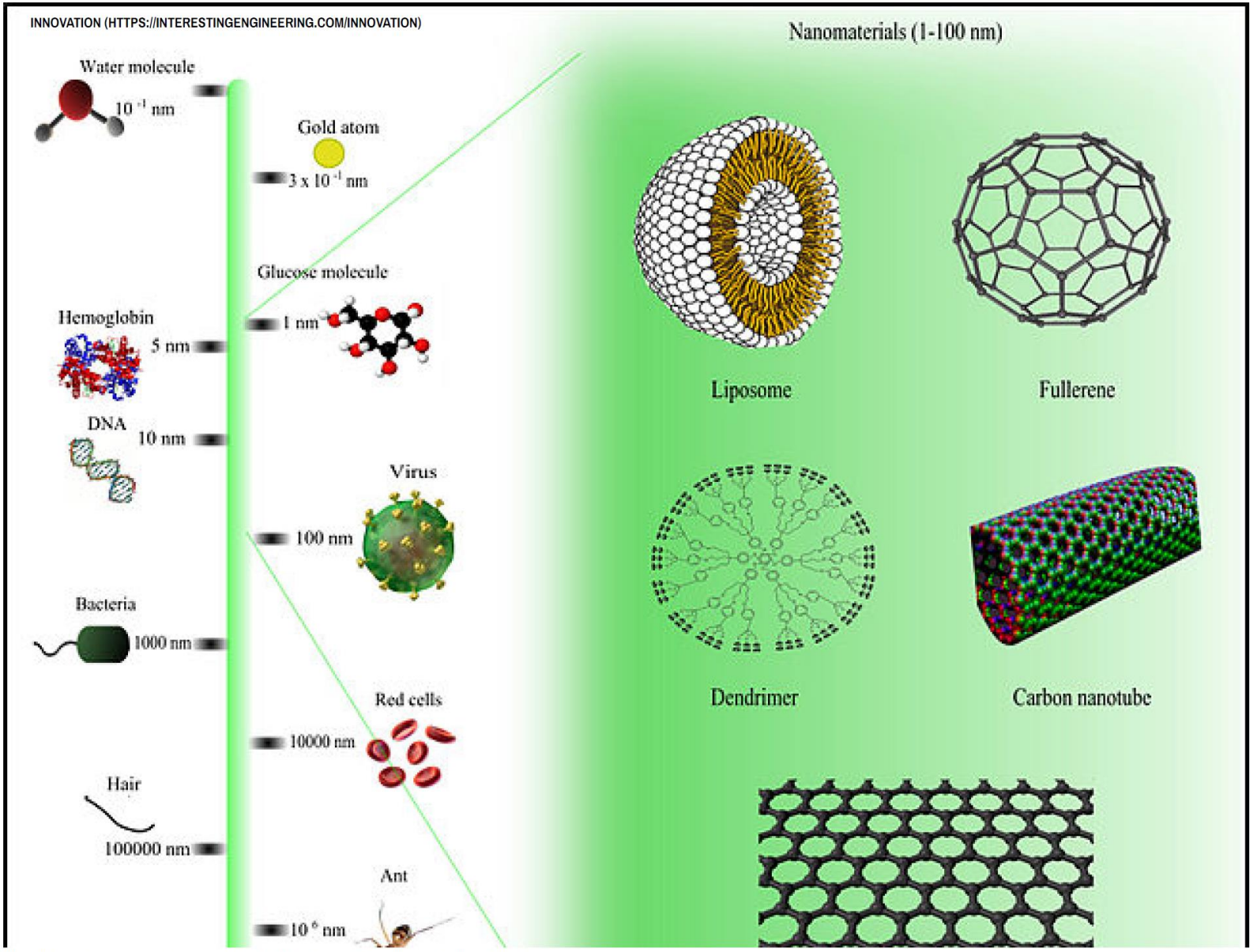



# FANTASTIC VOYAGE




Endoscope Camera




INNOVATION (HTTPS://INTERESTINGENGINEERING.COM/INNOVATION)
Nanomaterials (1-100 nm)
Water molecule
10 -1 nm
Gold atom
3 x 10 -1 nm
Glucose molecule
1 nm
Hemoglobin
5 nm
DNA
10 nm
Virus
100 nm
Bacteria
1000 nm
Red cells
10000 nm
Hair
100000 nm
Ant
10 6 nm
Liposome
Fullerene
Dendrimer
Carbon nanotube

# Aaron Becker UH  Nanorobots


Millirobots responds to magnetic field generated by MRI scanners.

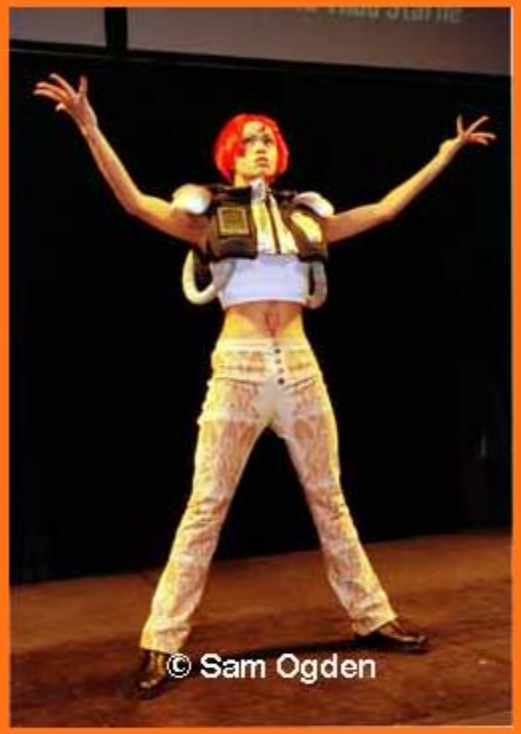
Could performing minor medical interventions, e.g. piercing a cyst and biopsies.

# THE FUTURE

- BIONIC PEOPLE
- ROBOTIC HOSPITALS
- ROBOTS FOR HOME CARE
- MICROROBOTS, NANOROBOTS

# THE FUTURE

Wearable Computer Fashion Show at MIT

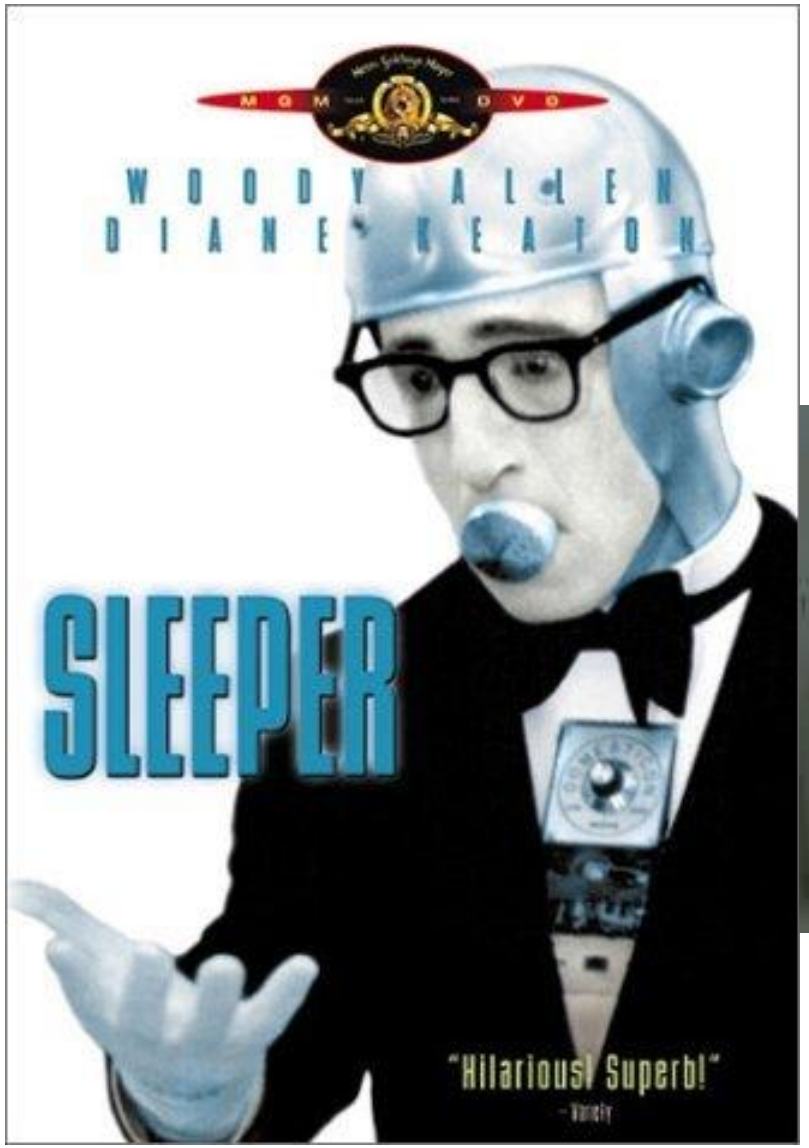



Wear it

next

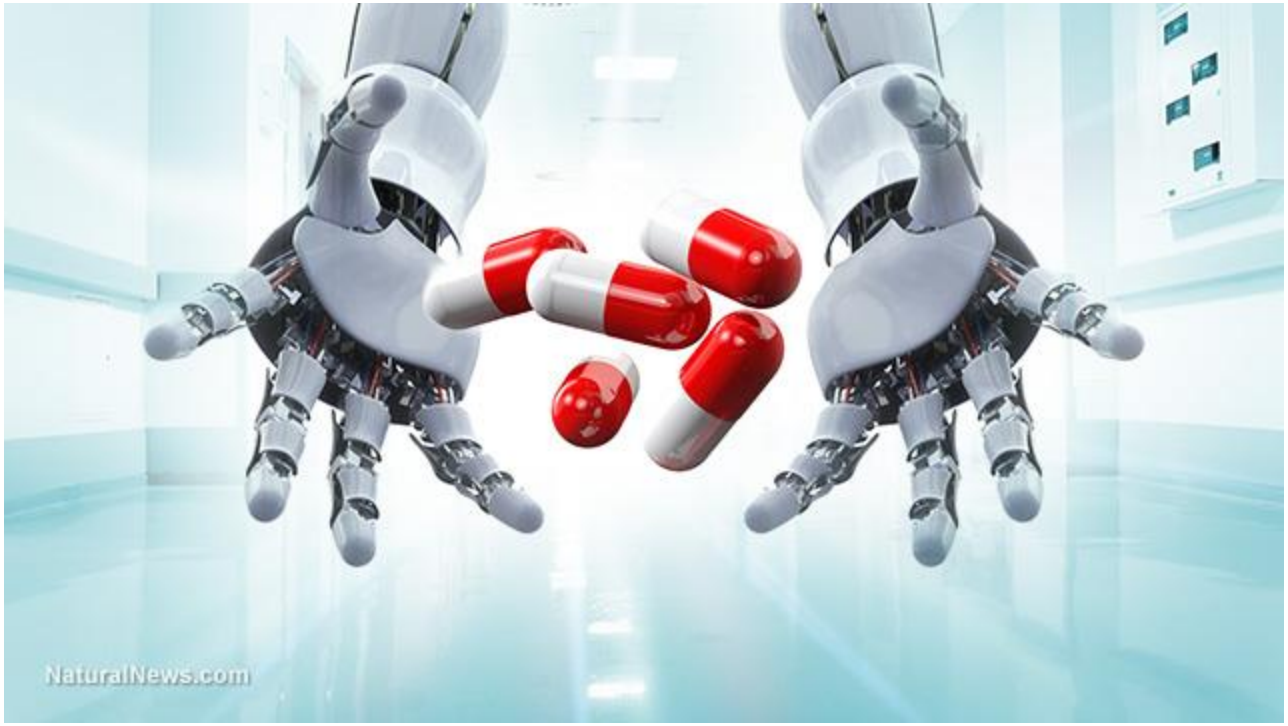
Back to Sam Ogden Photography

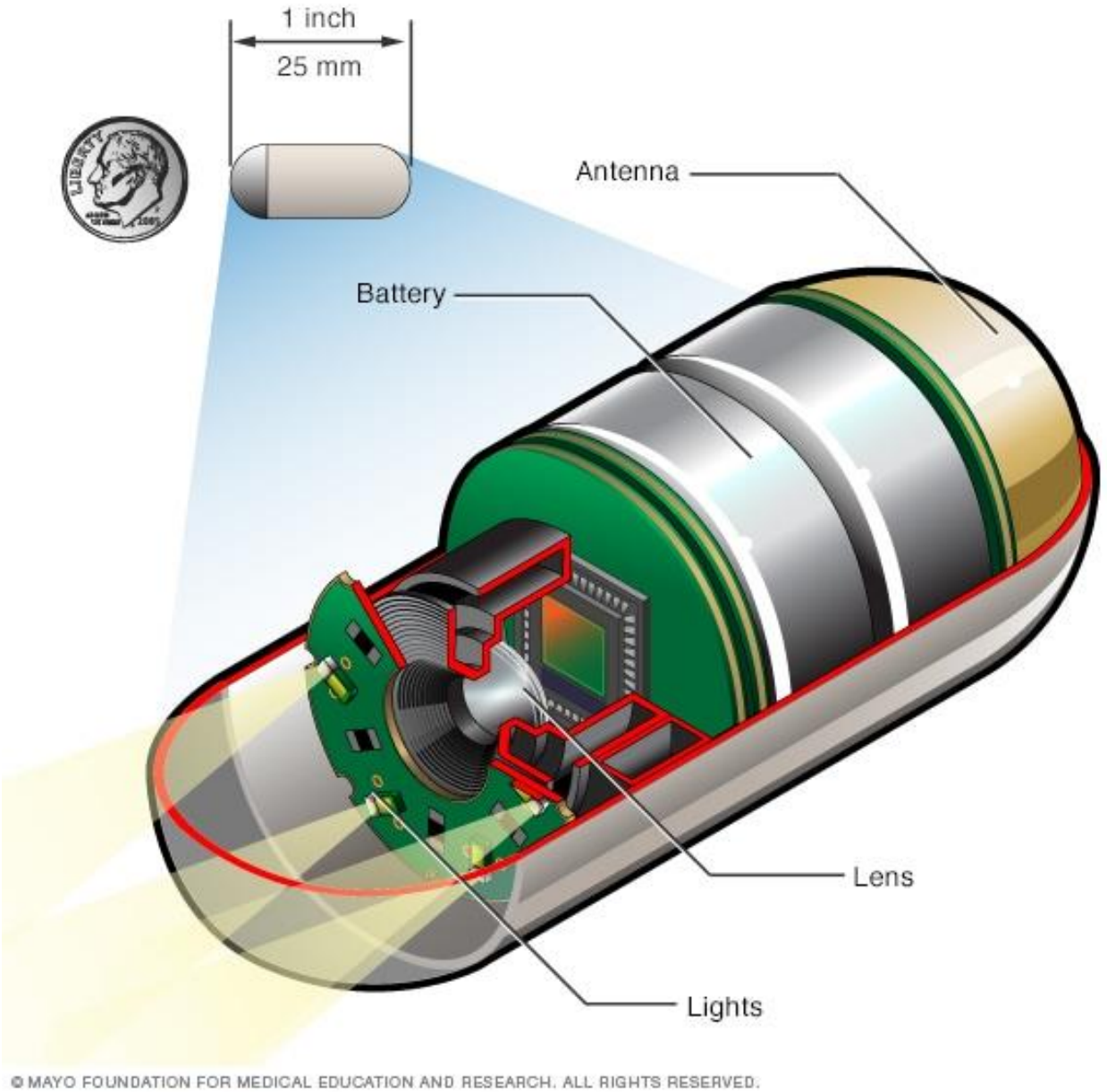
The SIX MILLION DOLLAR MAN and THE BIONIC WOMAN were inspired by the novel *Cyborg* (1972) written by Martin Caiden.




Robot Butler at Your Service!

Soon, robotic pills will usher in a new era in healthcare technology by reducing the number of surgeries altogether. Researchers are working on easy-to-swallow remote-controlled robotic pills. These pills will be able to move inside a patient's bodily fluids and deliver drugs to the desired area, conduct biopsies, film the area, and even clear clogged arteries. Exciting new robots such as nanobots can travel in the bloodstream with the help of light and remove tumors from the body.



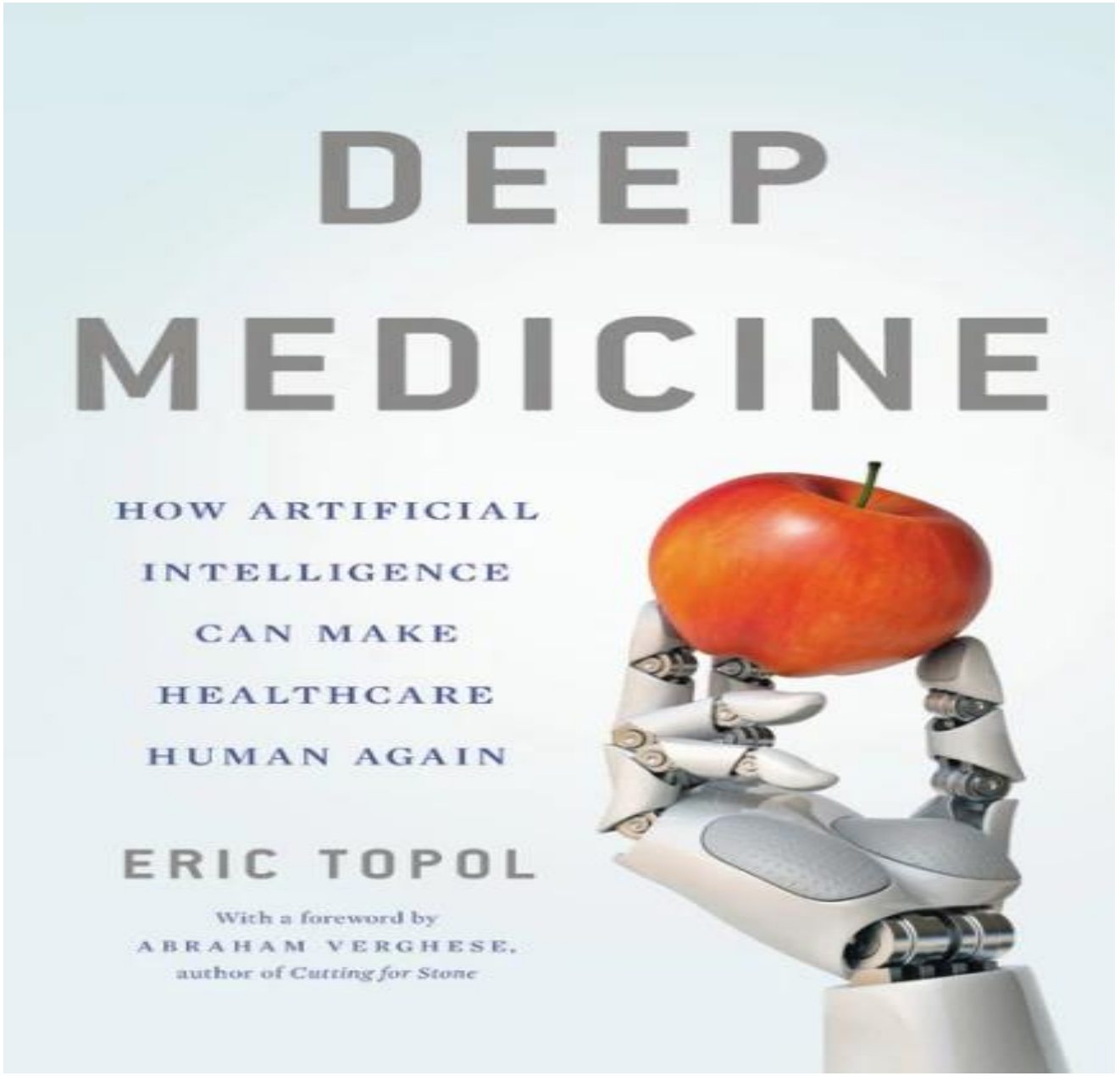


**Capsule endoscopy** is a procedure that uses a tiny wireless camera to take pictures of your digestive tract. A capsule endoscopy camera sits inside a vitamin-size capsule you swallow. As the capsule travels through your digestive tract, the camera takes thousands of pictures that are transmitted to a recorder you wear on a belt around your waist.

MAYO CLINIC

# Grace at Your Service


https://www.youtube.com/watch?v=ByLiGisgpN0


DEEP
MEDICINE
HOW ARTIFICIAL
INTELLIGENCE
CAN MAKE
HEALTHCARE
HUMAN AGAIN
ERIC TOPOL
With a foreword by
ABRAHAM VERGHESE,
author of Cutting for Stone


PRICE $8.99
THE
NEW YORKER
OCT. 23, 2017

"Nurse, get on the internet, go to SURGERY.COM, scroll down and click on the 'Are you totally lost?' icon."

Thank you for your Attention!!!

Any Questions?

# ENGINEERING CONTRIBUTION

- COMPUTERS AND COMMUNICATION
- MAN-MACHINE INTERFACES
- MODELING OF BIOLOGICAL SYSTEMS
- ADVANCED CONTROL METHODS
- MEMS (Micro-electromechanical Systems)

# ROBOT SPECIFICATIONS

- DEXTERITY
- ACCURACY (PRECISION)
- SMALL SIZE
- FEEDBACK (Visual, Tactile)
- USER INTERFACES
- VISUAL PRESENTATION (2D, 3D, etc.)
- SAFETY

# Computer Advances

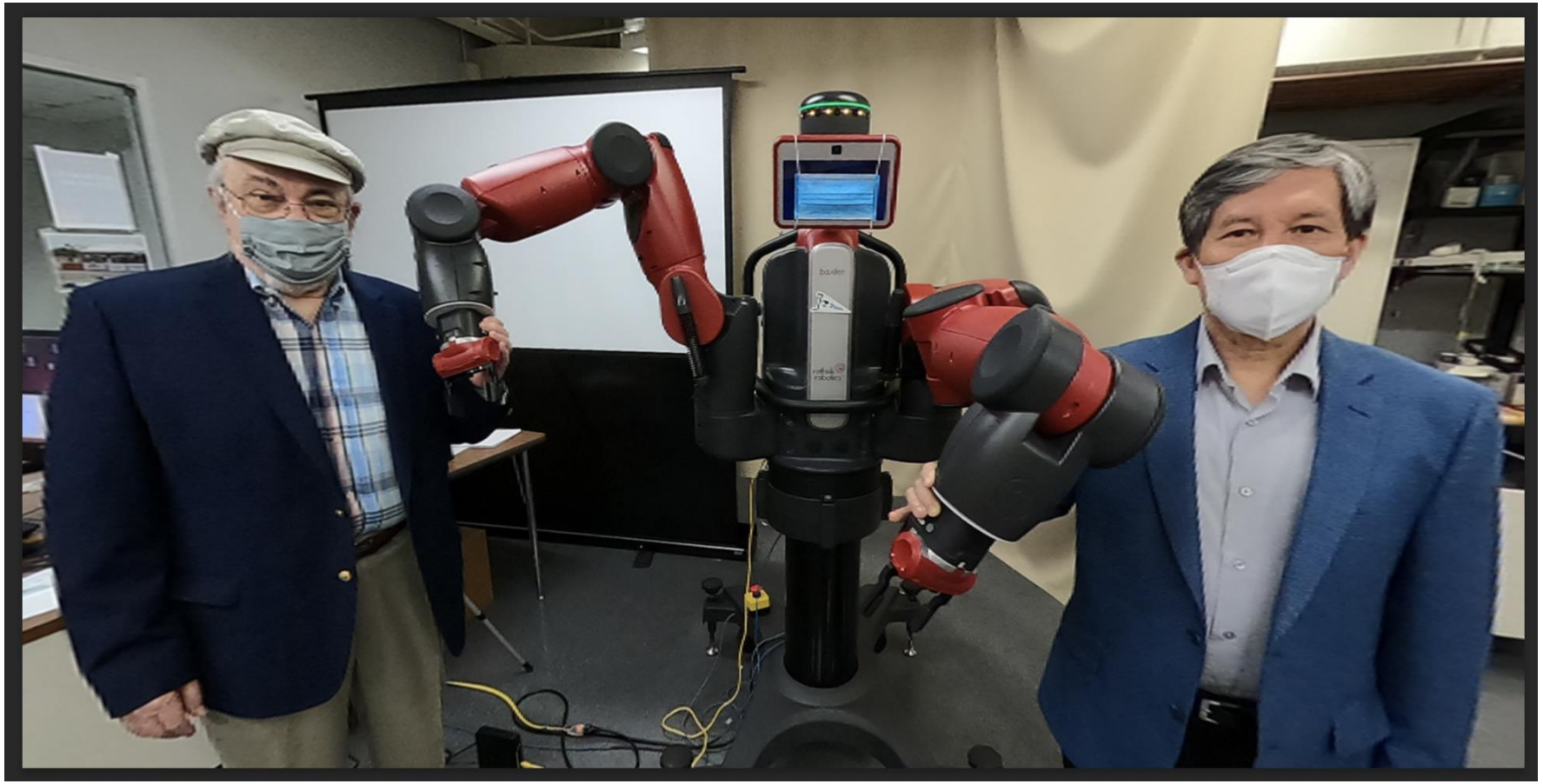
- RAW PROCESSING POWER
- *"Today, your cell phone has more computer power than all of NASA back in 1969, when it placed two astronauts on the moon."*

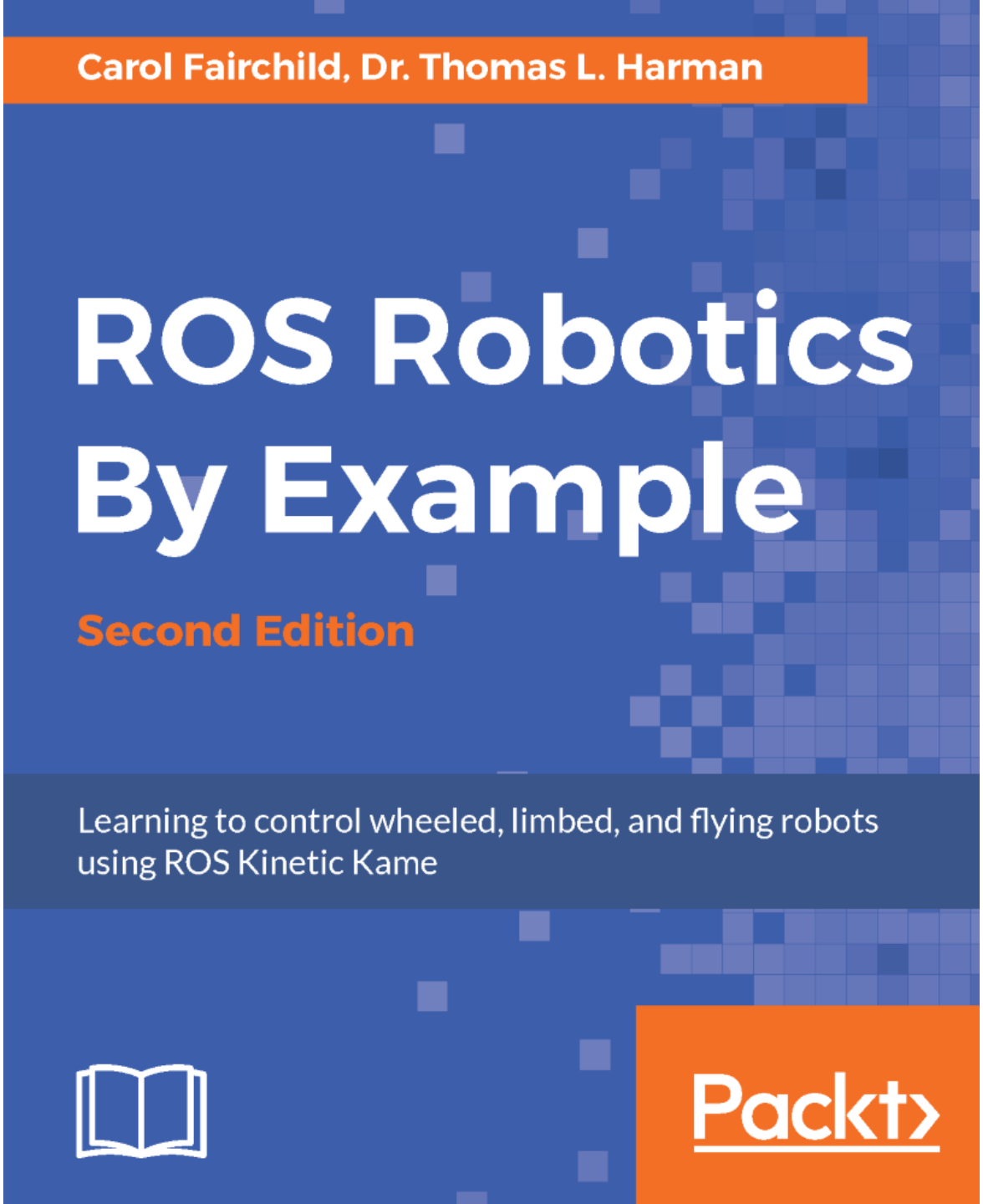
  Dr. Michio Kaku

# MEMS Systems

- Since their early stages of development, micro-electro-mechanical systems (MEMS) have shown potential for breakthroughs in the fabrication of medical tools.
- December 15, 2021

# SOME PERSONAL VIEWS




Carol Fairchild, Dr. Thomas L. Harman
ROS Robotics By Example
Second Edition
Learning to control wheeled, limbed, and flying robots using ROS Kinetic Kame
Packt

# ISSAC ASIMOV


300 BOOKS!

# Asimov's Take on Life

"If the doctors told me I had six months to live, I'd type a little faster."

Isaac Asimov

# TECHNICAL CONSIDERATIONS for COMMUNICATION

- Reducing Timing Delays
- Reliability
- Security

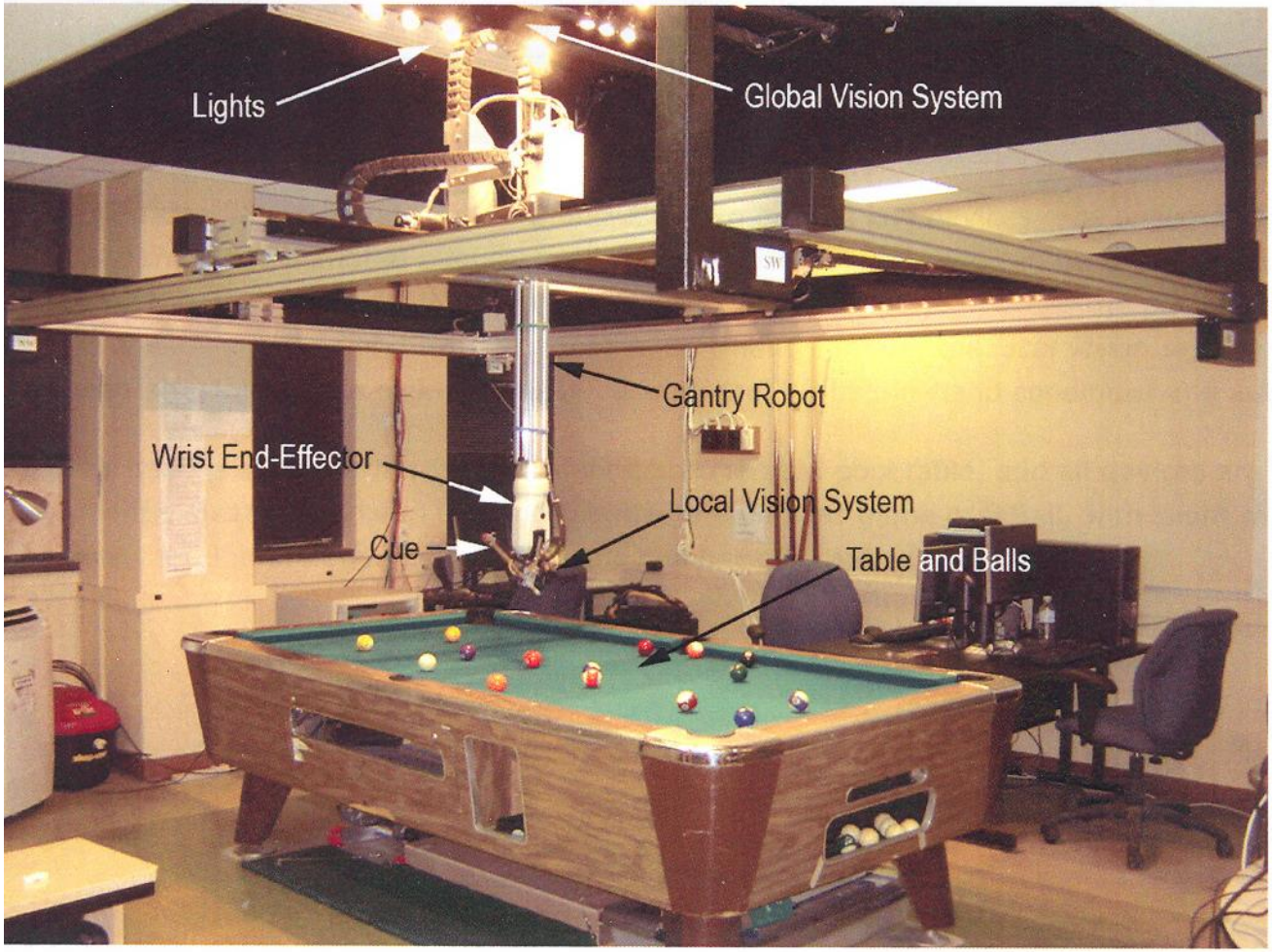
# LEGAL AND PRIVACY ISSUES

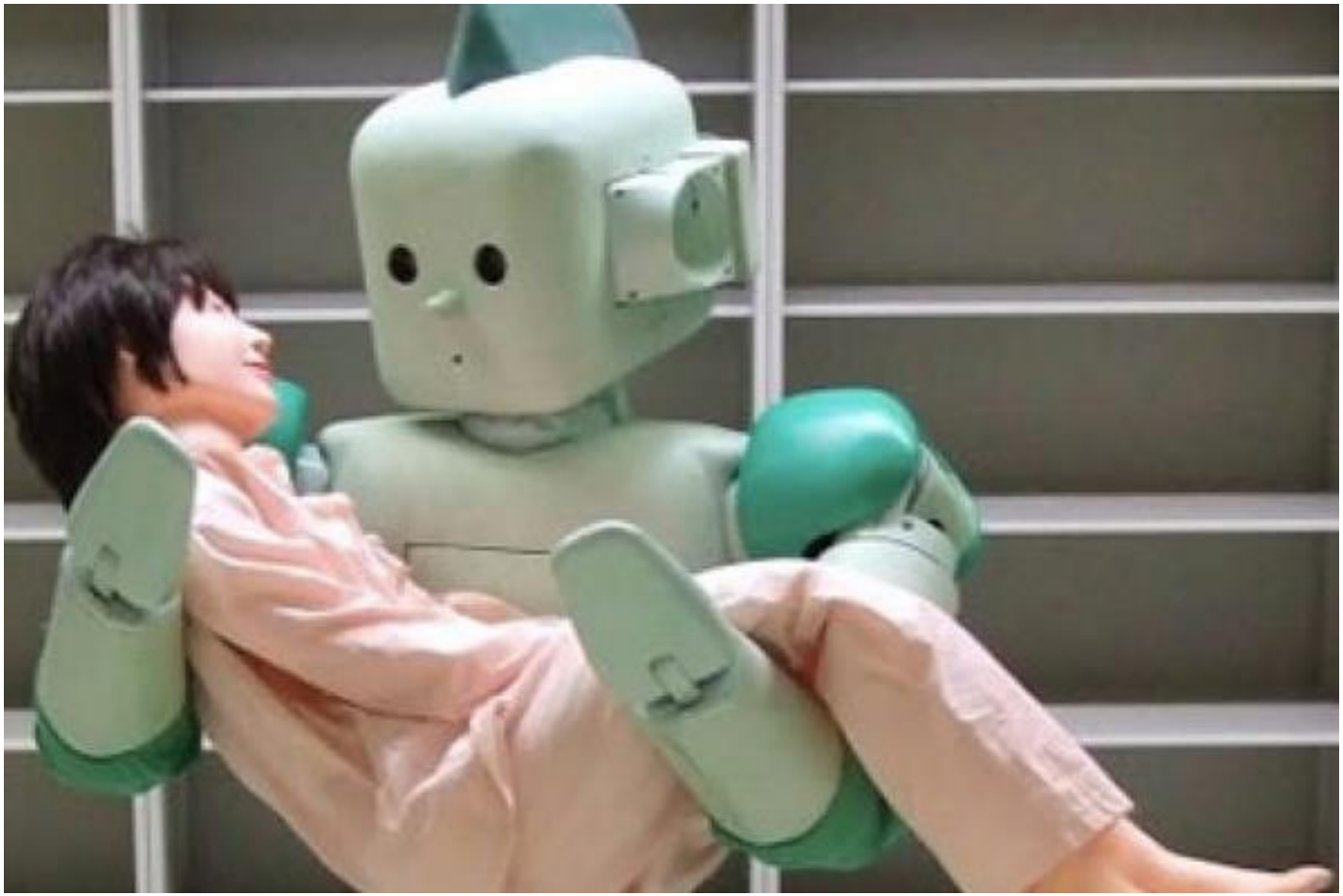
1. What kind of personal information is being collected?
2. From what sources is it being collected?
3. How is it being used?
4. How might it be shared and with whom?
5. Where does that information go at the end of its usefulness? Is it returned, deleted, archived, or sent somewhere else?

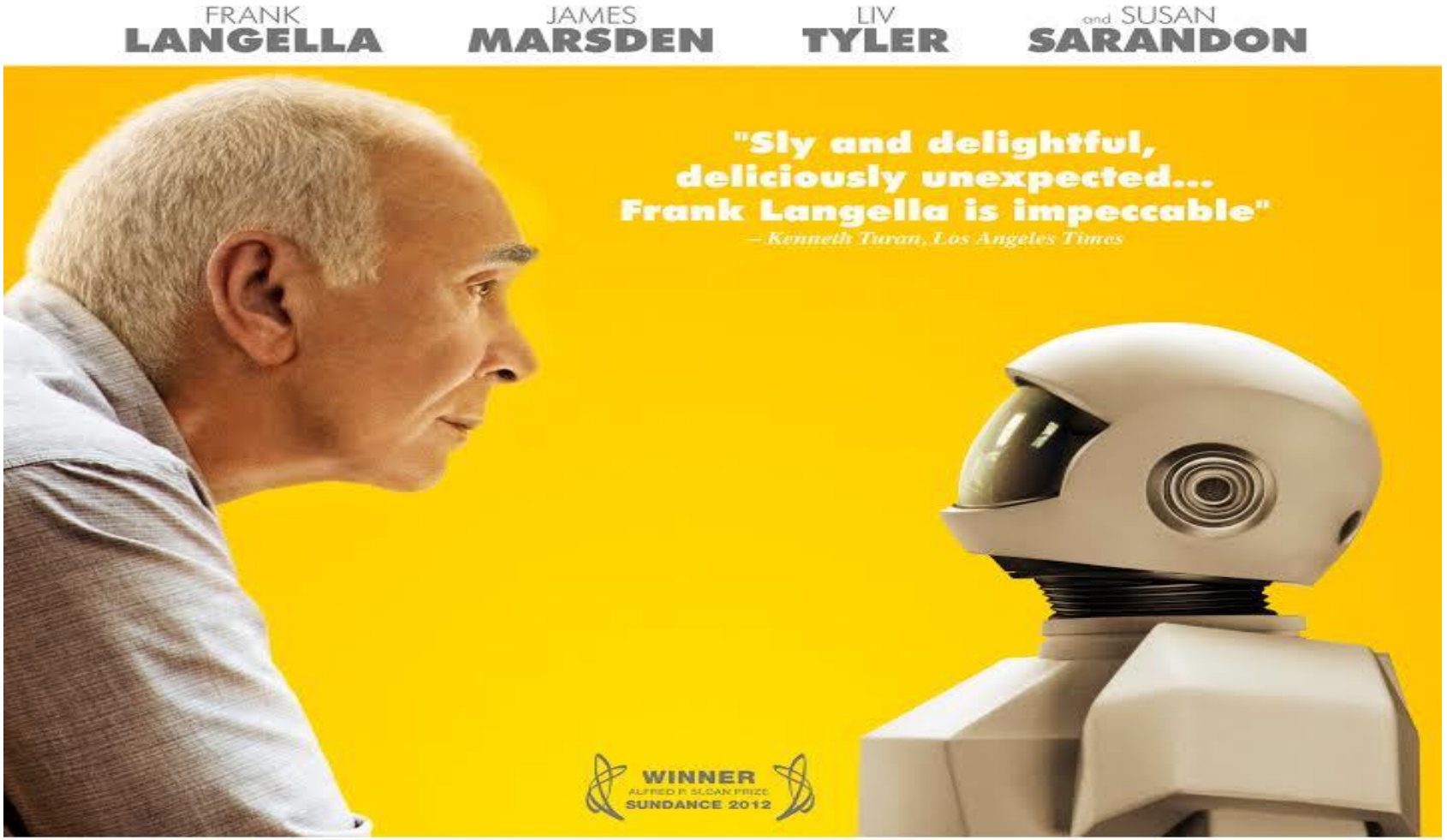

国際研究交流大学村
TOKYO ACADEMIC PARK


ASIMO
HONDA

# A “Better than Amateur Player”






FRANK
LANGELLA
JAMES
MARSDEN
LIV
TYLER
and SUSAN
SARANDON
"Sly and delightful,
deliciously unexpected...
Frank Langella is impeccable"
– Kenneth Turan, Los Angeles Times
WINNER
ALFRED P. SLOAN PRIZE
SUNDANCE 2012
ROBOT&
FRANK
FRIENDSHIP DOESN'T HAVE AN OFF SWITCH.

# THE FUTURE?