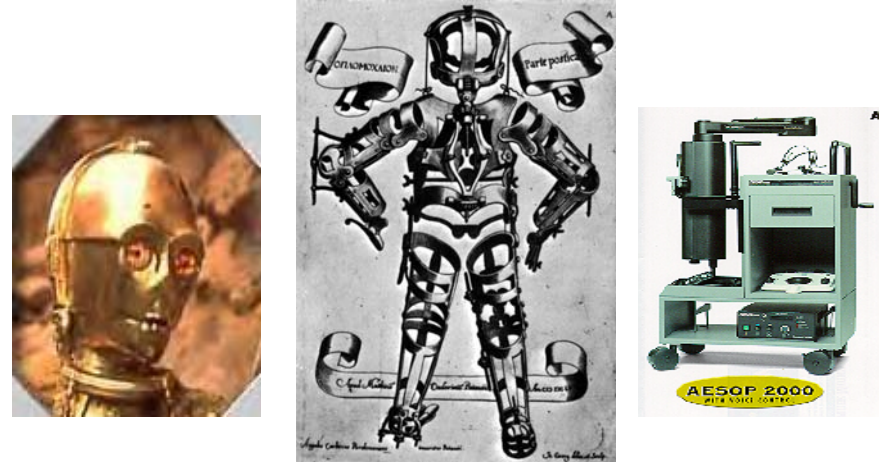


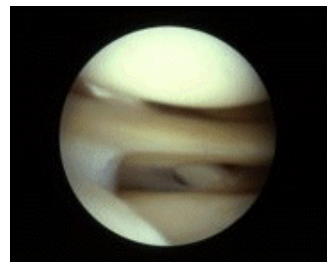
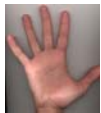
Robotic for a cardiac surgeon



N. Bonnet La Pitié-Salpêtrière

Surgery: kheiros

- Surgery
- Mini-invasive
- Video-assisted
- Videoscopic
 - celioscopy
 - thoracoscopy
 - arthroscopy...
- Robotic



Is mini-invasive surgery new?

Morton, Warren
et l'Ether

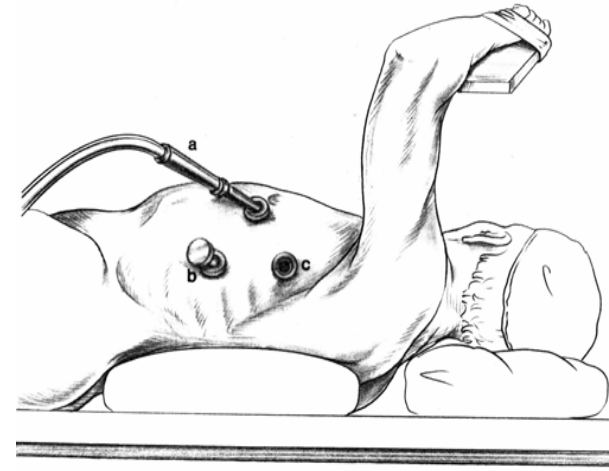


Ambroise Paré



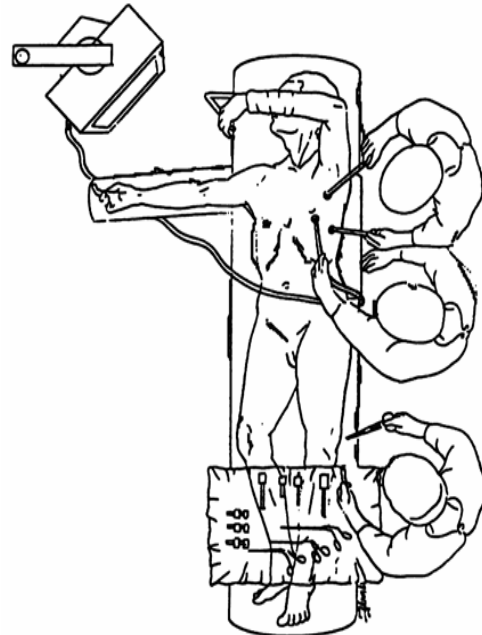
Mini-Invasive Surgery

- Two direction
 - No CEC
 - Small wounds
 - Both (TECAB)



**Trocart for
ITA
harvesting
during
thoracoscopy**

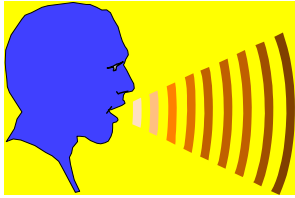
Thoracoscopic
ITA harvesting



Why do we need surgical robots?

- Better procedures:
 - Direct Enhancement of the quality
 - Mini-invasive surgery
 - Surgical precision
 - Enhancement of the quality via
 - Training of the surgeons
 - Ergonomy...
- New procedures
 - ?

Aesop 3000

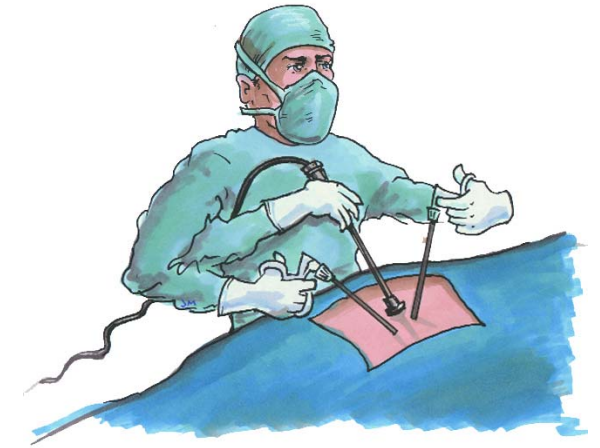


- Arm for the Endoscope
- Motor
- 3 ddl
- Voice Command

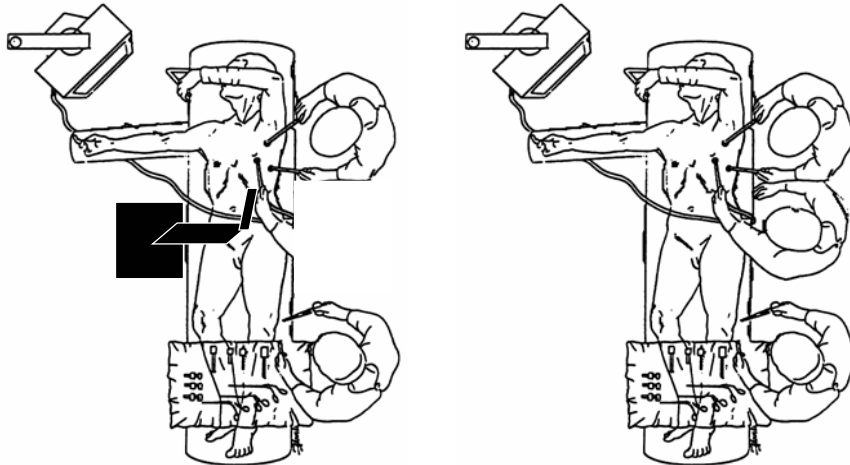


Aesop 3000 robot

- Stability
- Ergonomy
- 3^d hand for the surgeon



Placement d' Aesop



History robota

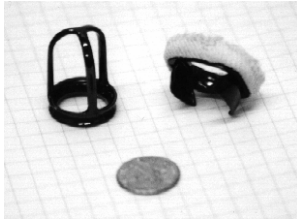


- 1921, Karel Capek
RUR: Rossum 's Universal Robot
- 1961, 1st robot is industrial
 - Productivity
 - Dangerous works



Robots for medicine

- Industry (fabrication)
- Robot in the laboratories
- Surgical Robot...



Robots at hospital

- Surgical Robots
- Robots for drugs delivery
- Robots for transport:
 - patients
 - bags
 - family (Welcome Robots)
- Robots harvester
 - blood: BloodBot de l'Imperial College of London
 - skin (Scallp Sinters)
- Robot - nurse...



Robot-Surgeon

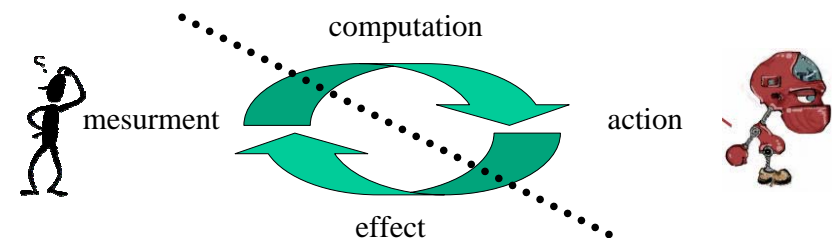
- Telemanipulation:
 - precision
 - Intracorporeal wrist
- Stereotaxy:
 - CASurgery
 - Preoperative simulation
- In the futur the robot should interact with the whole operative theater



The beginning

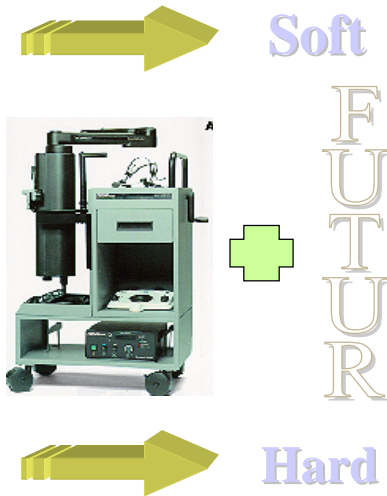
What is a robot for a surgeon?

- Essential Concept : retro-action
- Linked Concepts: mechanism and numeric



Surgical robots

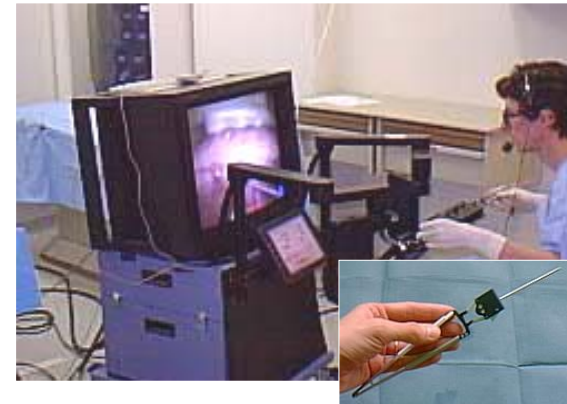
- Robots for all surgery:
 - Aesop™ (Computer Motion)
 - Zeus™ (Computer Motion)
 - DaVinci™ (Intuitive)
- Robots for specific
 - Caspar™ (Maquet)
 - Robots for neurosurgery or radiotherapy...



17

Teleoperators, general anatomy

Electronic Link

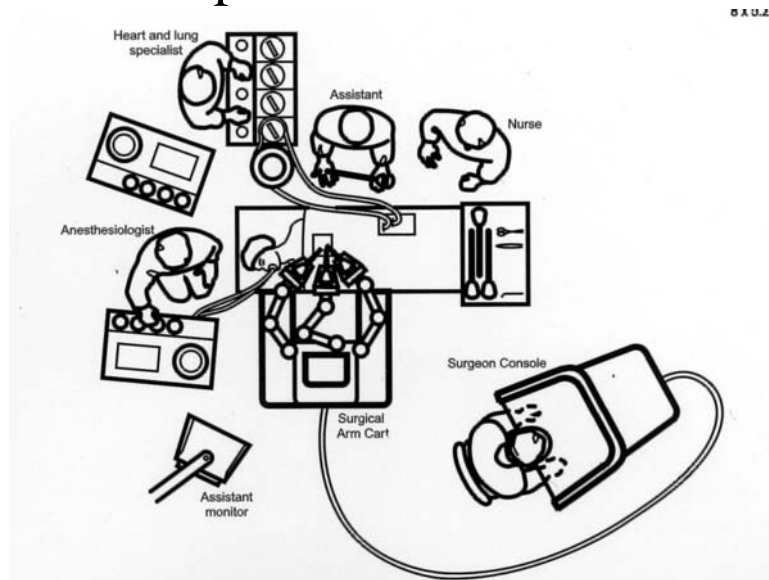


Console / Master

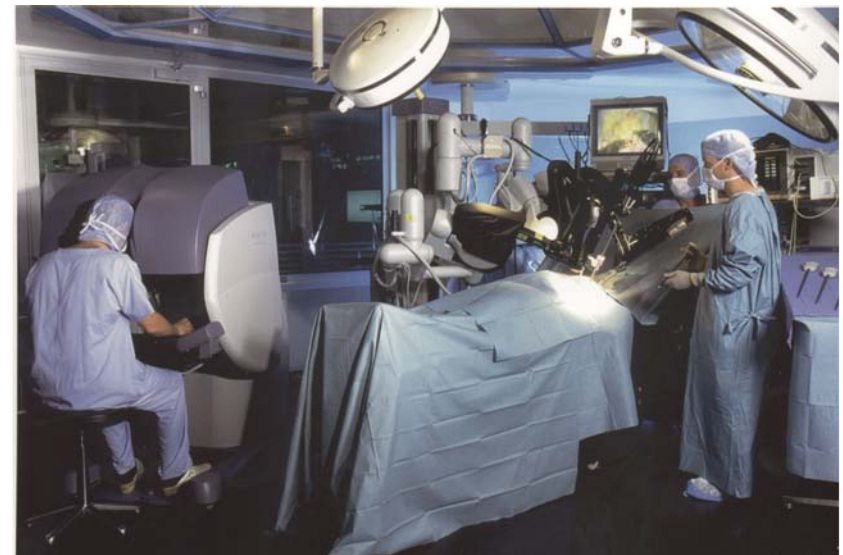


Bras effecteur / Slave

Teleoperator in cardiac OR



DaVinci at Broussais





DaVinci

da Vinci Surgical System
Dresden Heart Center O.R.

Zeus™, Computer Motion

- For endoscopic surgery
- 3 arms
 - 2 Zeus™ for instrument
 - 1 Aesop™ for endoscope



master



slave

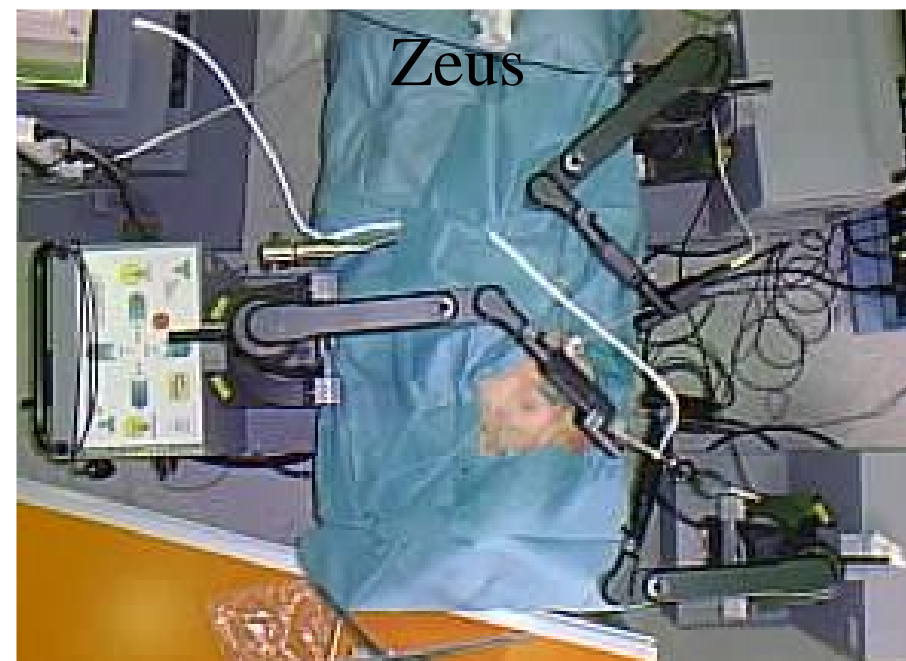


Tête



Tête

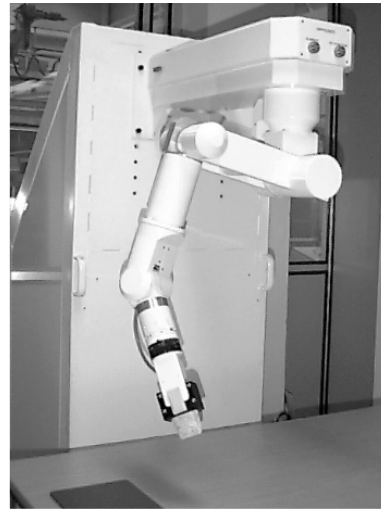
Computer
motion



Zeus

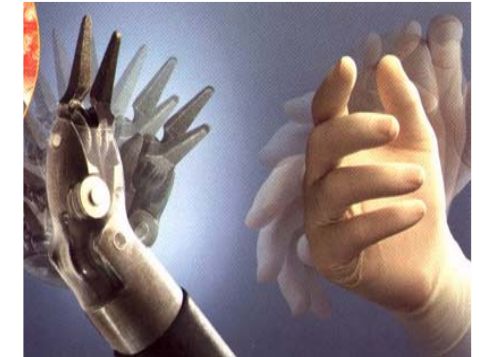
Two different concept

- multifunction
 - teleoperators
 - futur « robot-surgeon » (star war)
- unifunction
 - stereotaxy
 - futur « component of robot-surgeon »

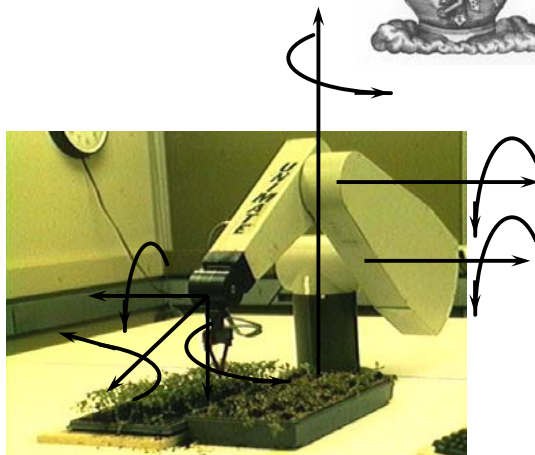
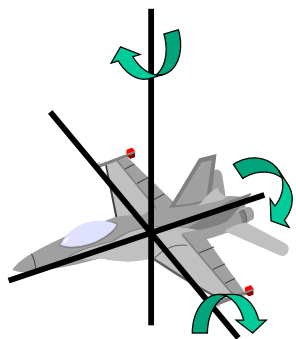


Analysis of the surgical procedure

- Types:
 - Taking and holding (pince)
 - rotation (screwing, perceuse...)
 - others!!!
- Precision
- Haptic
- Force

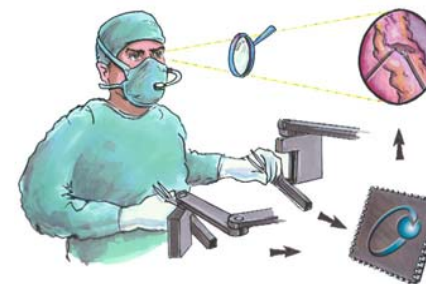


dof



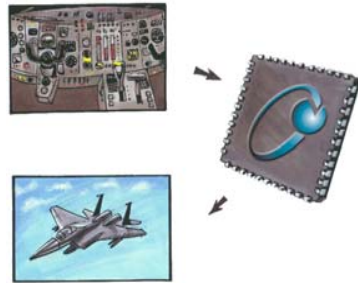
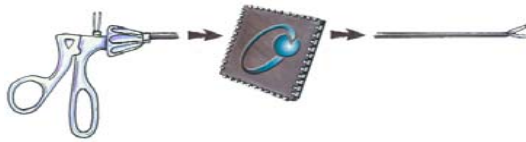
Amplification / Adaptation

- force et skill
- stability
- precision, filter
- rapidity
- reproducibility...



Interests of teleoperator

- Now
 - Precision
 - Dexterity
 - Ergonomy
 - Plug and play
 - 3^d hand
 - Intrathoracic wrist
- Futur:
 - Complex motion
 - automatisaion
 - haptic
 - stereotaxy
 - teleoperations
 - teaching



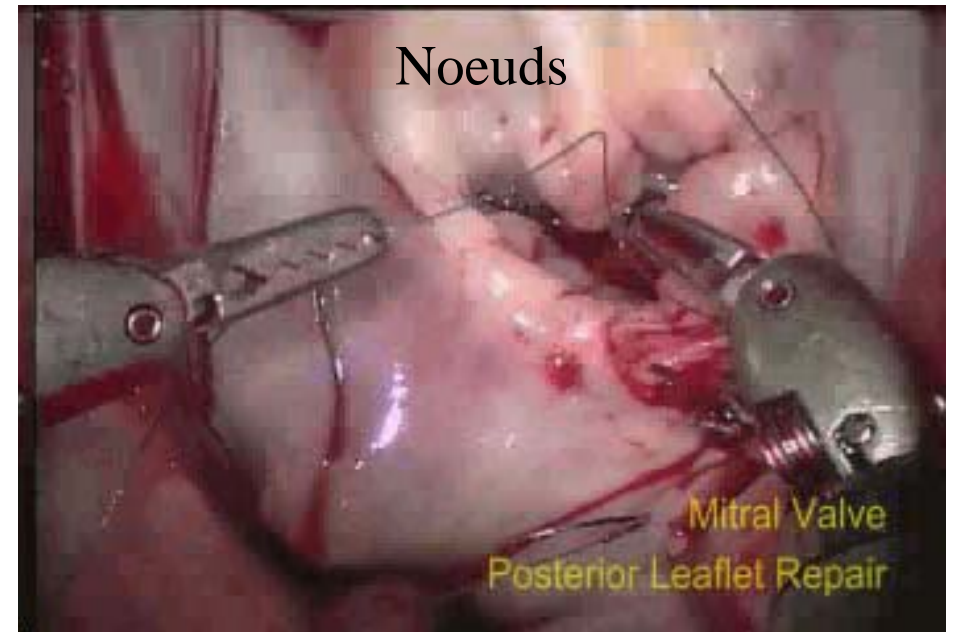
Intrest of teleoperator



Intracorporal wrist



Noeuds

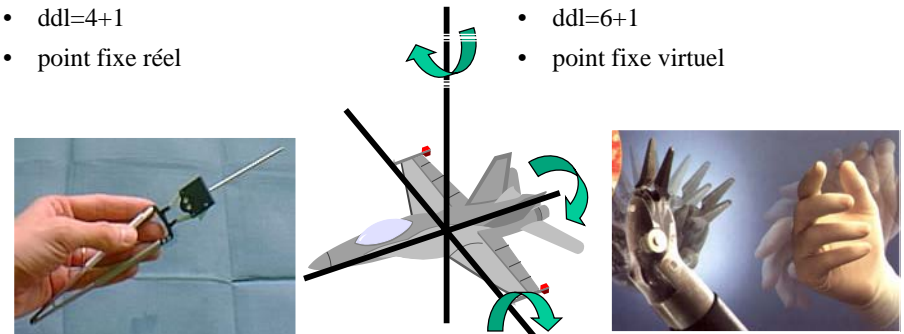


Découplage des axes



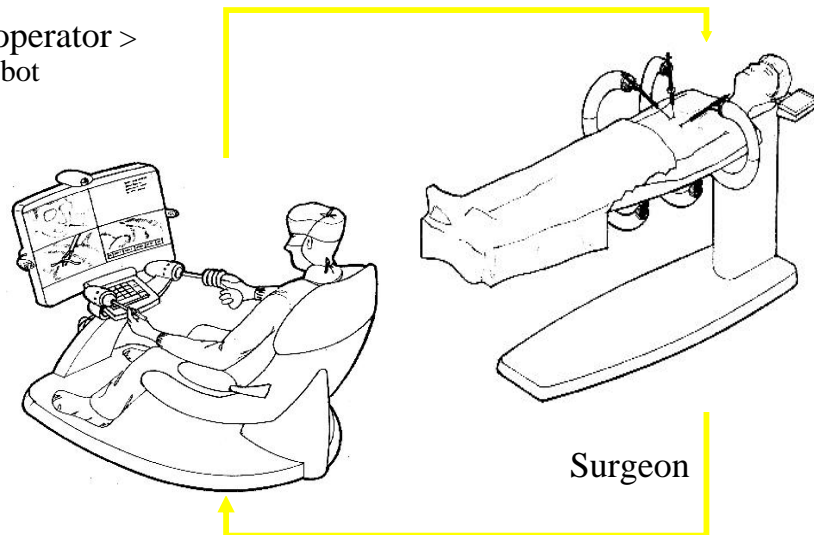
Zeus™ -vs- DaVinci™

- | | |
|---|---|
| <ul style="list-style-type: none"> • Trois bras indépendants fixés sur la table • Colonne optique indépendante • Bras porte-optique commandé à la voix • ddl=4+1 • point fixe réel | <ul style="list-style-type: none"> • Trois bras liés sur un portique • Colonne optique intégrée avec vision 3D • Bras porte-optique commandé manuellement • ddl=6+1 • point fixe virtuel |
|---|---|



Zeus™ / DaVinci™ now

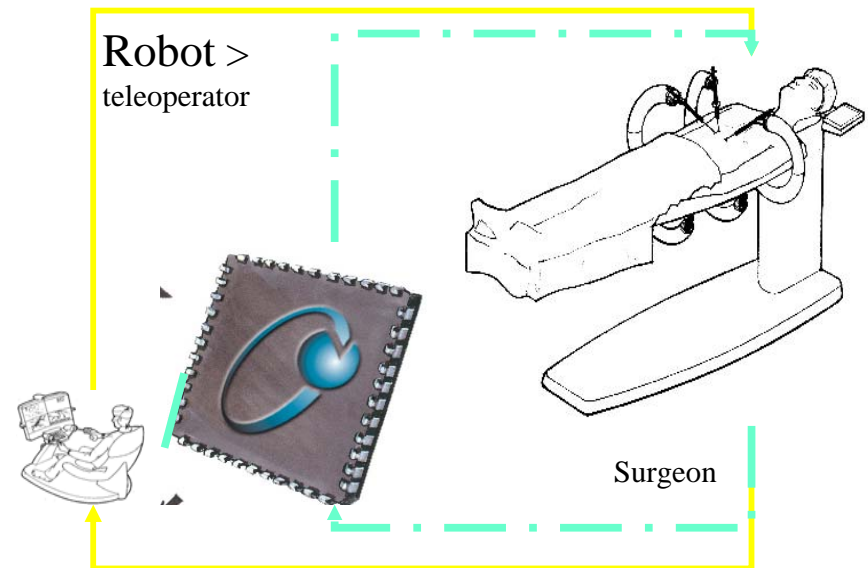
teleoperator > robot



Surgeon

Zeus™ / DaVinci™ futur

Robot > teleoperator



Surgeon



Surgeon Vishnu



News in endoscopy

- 3CCD
- High Resolution
- 3D
- Wide angle
- point of view
- angle of view
- numeric

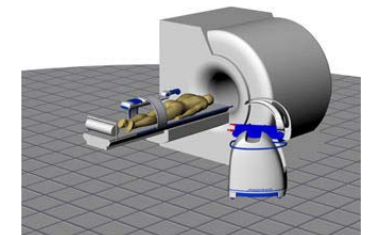
Videoscopy

- Smaller
- Automatic control
 - light
 - Contrast
 - focus
- Enhanced reality
- Chimène™ (Thomson/Genzyme)

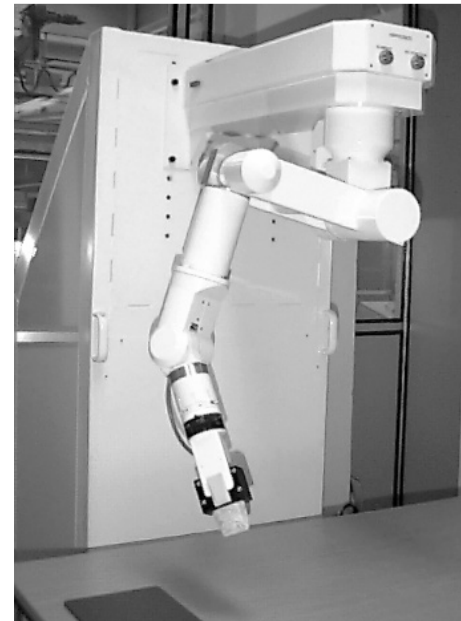
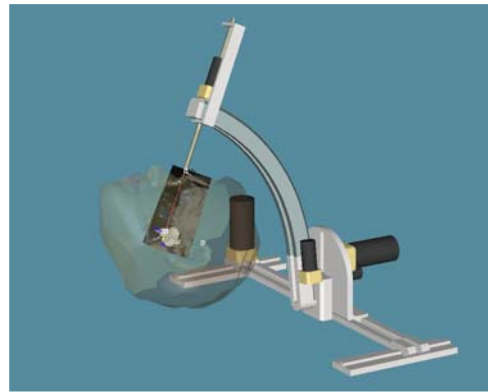
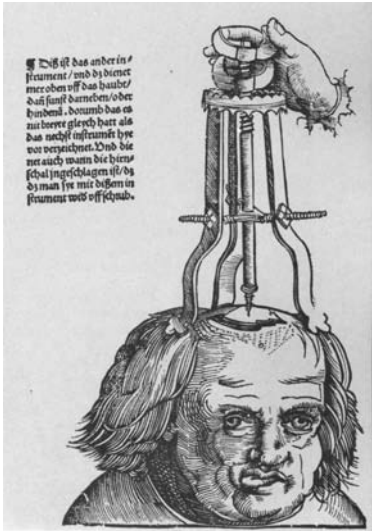


Other Robots

- Orthopedic
 - precision/simulation/stereotaxy
 - Hipnav, Caspar, Robodoc
- Neurosurgery
 - stereotaxy, neuronavigation
- Microrobots et endovascular surgery
- Radiointervention, radiotherapy
 - stereotaxy
 - Enhanced reality
 - radioprttection
- tele-echography...



Neurosurgery et stereotaxy



Hippocrate

- Reproductibilité
- Robot spécifique dédié
- Télédiagnostic

HERMES ,
 voice commad
 (table, lights, ... video...)

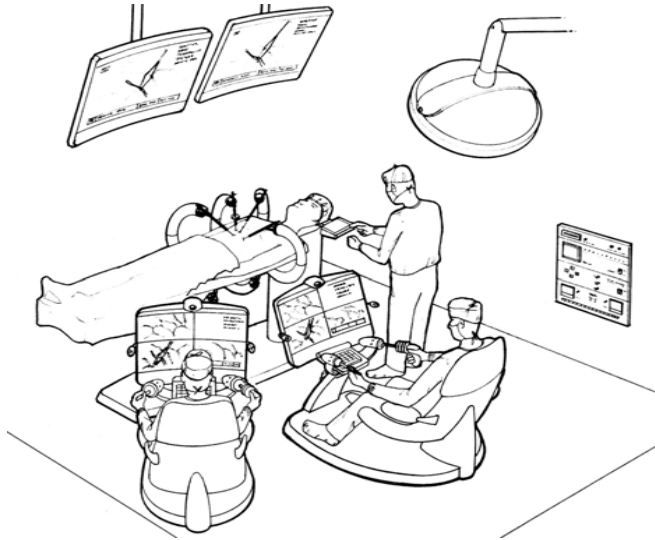


Telesurgery Lindbergh procedure



- industrial and médical Marketing
(G Landrion Nouvelles technologies et chirurgie du futur, Ed Arnette, 2000)
- Technological challenge
 - Real time master-slave (logiciels de prévision)
 - Safety of communication
 - Distributed net
- Telesurgery, where
 - Far away (Mars, Antartic...)
 - Closer (Other OR, same OR: cosurgery)

Futur OR



Current Customers

US Hospital Installations
As of July, 2004



Europe Hospital Installations
As of July 2004



Current Customers

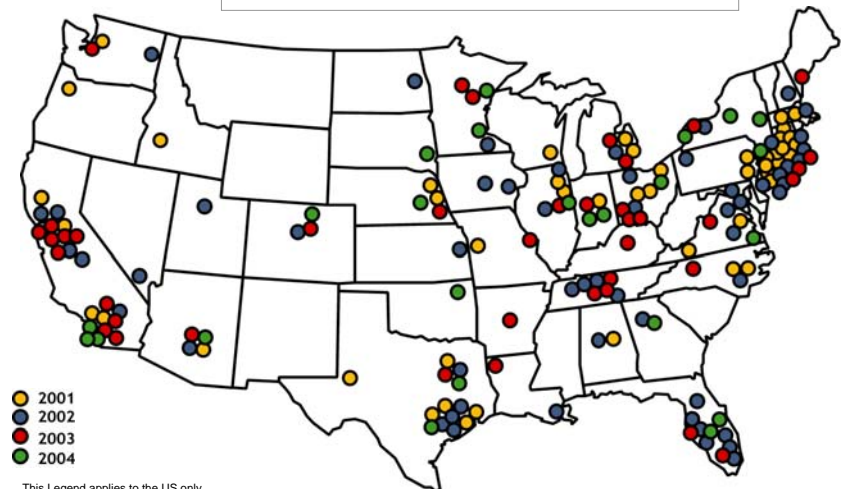
Far East Hospital Installations
As of July, 2004



Canada Hospital Installations
As of July, 2004



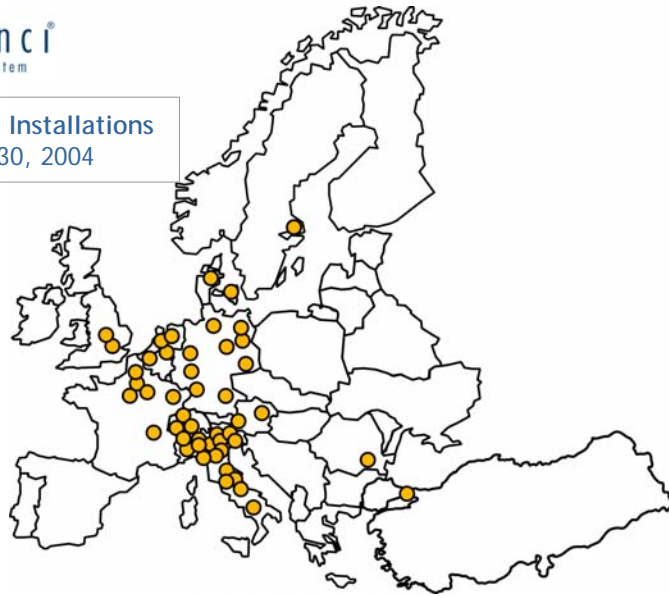
US Hospital Installations
As of June 30, 2004



- 2001
- 2002
- 2003
- 2004

This Legend applies to the US only

Europe Hospital Installations
As of June 30, 2004



Current Customers

Middle East Hospital Installations
As of July, 2004



Teleoperators in cardiac surgery

Endoscopic surgery

- « classical » / without suture
 - ITA harvesting (Juillet 99 avec Zeus à la Pitié)
- « new » / with sutures
 - 1^{er} TECAB off pump Janvier 2000 Pr Mohr (Allemagne)
 - Mitral surgery Heart Port



CABG

- Grafts harvesting (LITA RITA)
- Opening the pericardium
- Coronary identification
- Coronary stabilisation
- Arteriotomy
- Temporary hemostasis
- Anastomosis

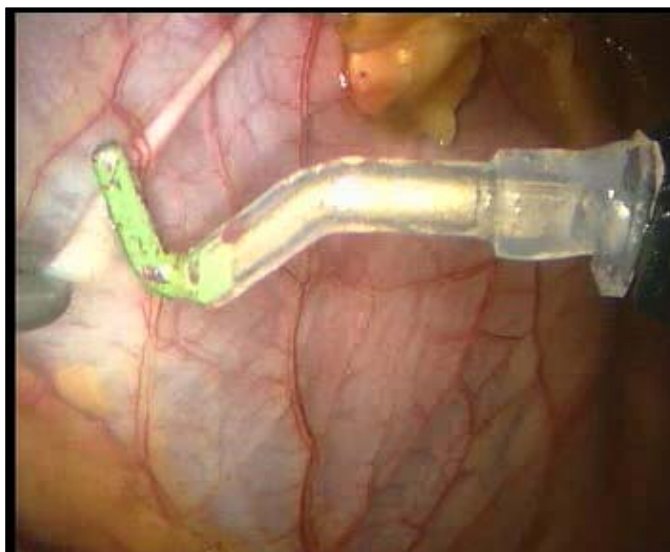
With intracorporeal wrist,
coronary anastomosis



Mediastinum



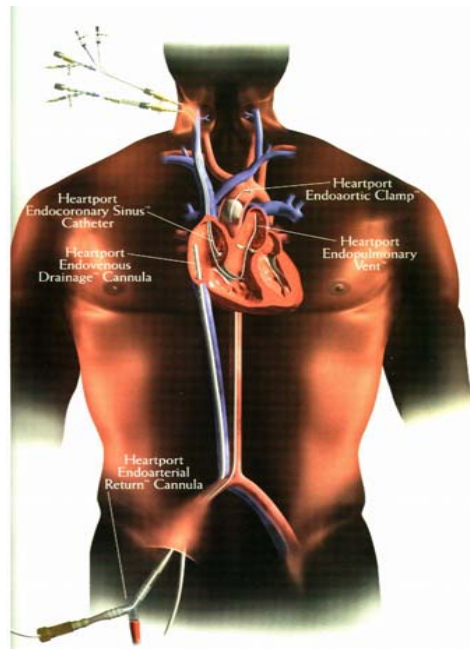
Ventricular resynchronisation
LV epicardial leads



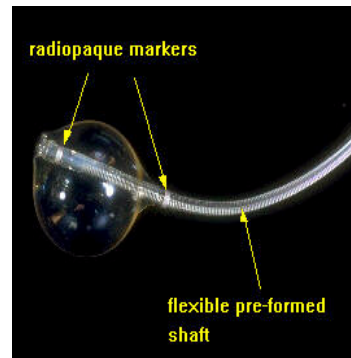
Valvular surgery

- With heart-port technology:
 - Femoral ECC
 - Aortic XClamp
 - Small thoracotomy
- Mitral and tricuspid
- Totally endoscopic procedure





Heart Port



Knots



ASD

- ASD Repair
 - FDA Multicenter Trial
 - Thoracoscopic Cardiotomy procedure claim - January 2003
 - Totally Endoscopic Approach
 - Excellent surgical alternative for active patients seeking minimal disruption in quality of life



da Vinci™ Procedures Completed



Cardiac- Vascular & Thoracic

- Endoscopic Single Vessel Beating Heart Bypass, LIMA-LAD
- Endoscopic Double Vessel Beating Heart Bypass, LIMA-LAD & RIMA-RCA
- Endoscopic Arrested Heart Single Vessel Bypass, LIMA-LAD or RIMA-RCA
- Endoscopic Arrested Heart Multi-Vessel Bypass

Beating Heart Single Vessel Bypass LIMA-LAD

- IMA Harvesting
- Bilateral IMA Harvesting
- Coronary Anastomosis
- Atrial Septal Aneurysm
- Subrenal Aortic Aneurysm
- Atrial Septal Defect Repair
- Mitral Valve Repair & Replacement
- Tricuspid Valve Repair
- Thrombectomy
- Pericardial Window
- Lobectomy
- Pneumonectomy
- Abdominal Aortic Aneurysm
- Aortic Femoral Bypass
- Pacemaker Lead Implantation
- Mediastinal Resection
- Pulmonary Wedge Resection





Multi-Specialty Solutions: Cardiac/Thoracic

IMA Takedown

Mitral Valve Repair

Epicardial Lead Placement

Beating Heart TECAB (Single Vessel)

Arrested Heart TECAB (Single & Multiple Vessel)

Mediastinal Mass Removal

Pericardial Window

Sternotomy LIMA-LAD

Enhanced MIDCAB

Atrial Septal Defect

Esophagectomy

Thymectomy

Lobectomy

Wedge Resection

Mediastinal Tumor

Heller Myotomy

Esophageal Achalasia

Esophageal Mass Enucleation

Aortic Ring Dissection

Sympathectomy

Sympathectomy Total

Esophageal Myotomy

Splenic Artery Aneurism

Pulmonary Descending Aorta

Ligation

Aortic Coarctation

Cardiac – Mitral Valve Repair

Comparison of relevant clinical variables for Mitral Valve repair: Sternotomy vs. *da Vinci*® Surgical System

	2001 STS National Database Sternotomy Mitral Valve Repair***	da Vinci Mitral Valve Repair****	da Vinci MVR Post-Learning Curve
Number	893	22	12
Mortality	2.2%	0%	0%
Major Complications	13.1%	0%	0%
Neurological Complications	2.4%	0%	0%
Cross-Clamp Time (Min)	85.5	86	76
CPB (Min)	121	124	113
Post-Op-LOS (Days)	8.5	4.2	1.3

N=893 from The Society of Thoracic Surgeons (STS), National Cardiac Surgery Database, Isolated Mitral Valve Repair Procedures, Jan-Jun 2001 * Data from STS 2001 not available, ****Data used as part of 112 patient, multi-center, da Vinci mitral valve repair clinical trial; da Vinci Robotic Mitral Valve Repair; Outpatient Procedure? Pat S. Pappas, M.D., et. al; Advocate Christ Hospital, Chicago, IL

Contraintes conceptuelles

- Robustesse
- Encombrement
- Stérilisation
- Coût
- Pilotage par des personnels non roboticiens

ce que veulent les roboticiens

Décrire et quantifier avec précision les gestes d'une intervention

- Convergence des disciplines
 - robotique
 - automatisme
 - mécanique
 - simulation...
 - médecine
 - autres
 - psychologie
 - économie...

