# haptics technology and applications

EPF, Lausanne, Switzerland
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personal
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company

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haptic interfaces
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simulation
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# human perception

force dimension

# human perception

Lateral Motion
(Texture)

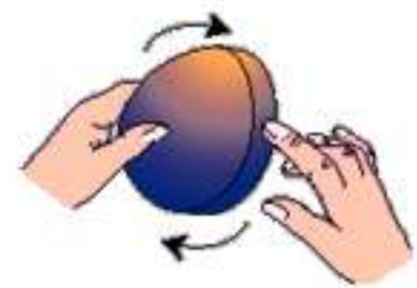
Pressure
(Hardness)

Static Contact
(Temperature)

Unsupported Holding
(Weight)

Enclosure
(Global Shape)
(Volume)

Contour Following
(Global Shape)
(Exact Shape)



Susan Lederman and Roberta Klatsky

# human perception

## what is haptics?

- physical interaction via the sense of touch

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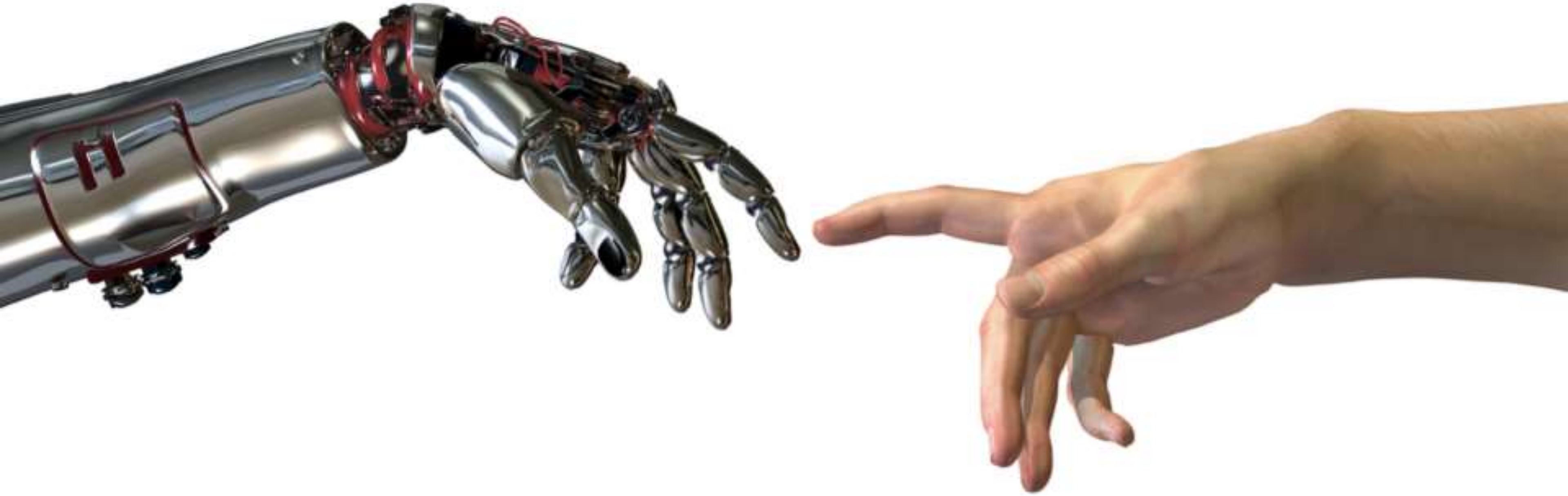
# human perception

## what is haptics?

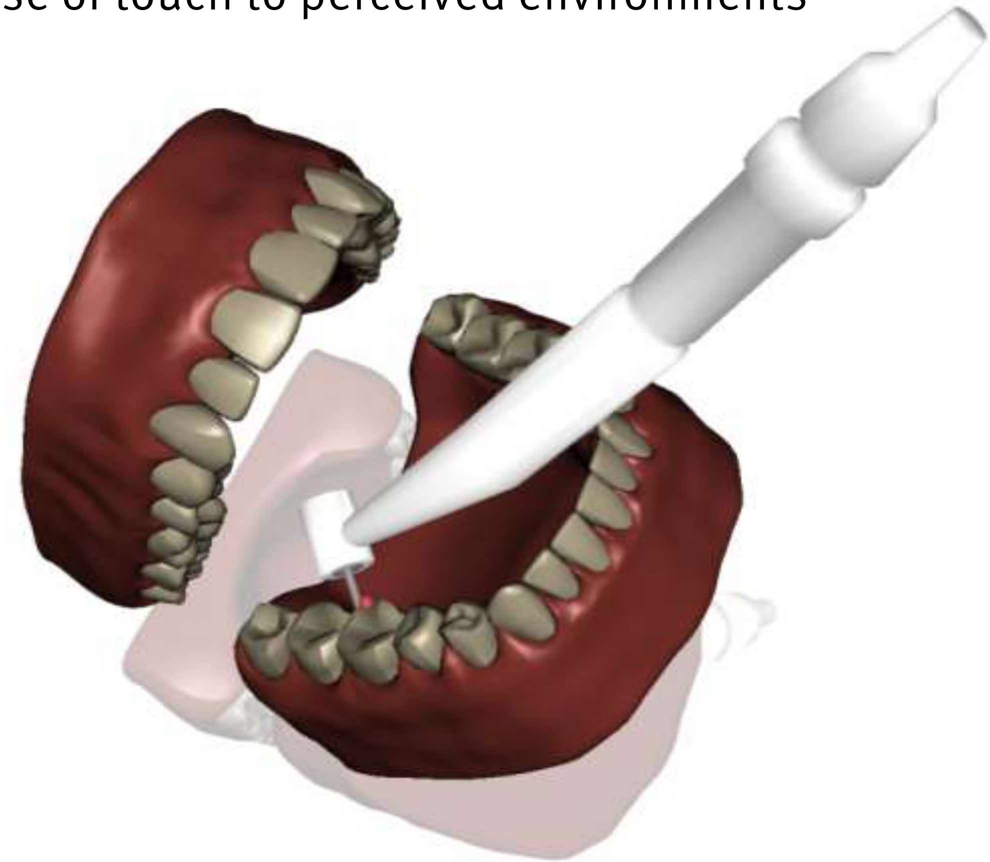
- using the sense of touch to interact with machines



# human perception

## why use haptics?

- to add the sense of touch to perceived environments



## human perception

### why use haptics?

- to allow real-time co-operation between man and machine

mouse / joystick →

keyboard / buttons →

voice / gesture →

← visual

← audio

↔ haptic

analysis
intelligence

human in the loop !

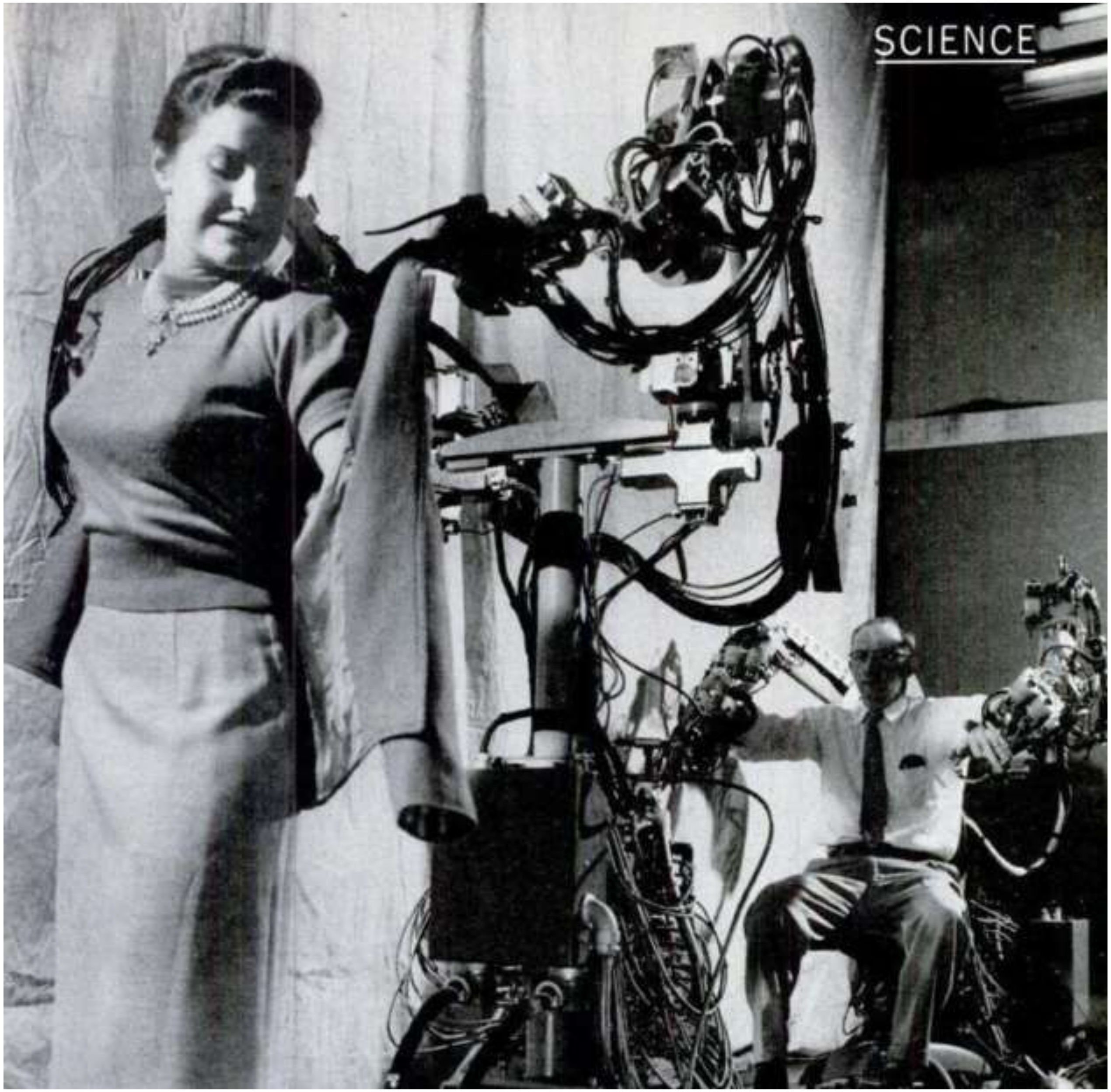
performance
task adaptation

# robots and humans

- Life Magazine 1956

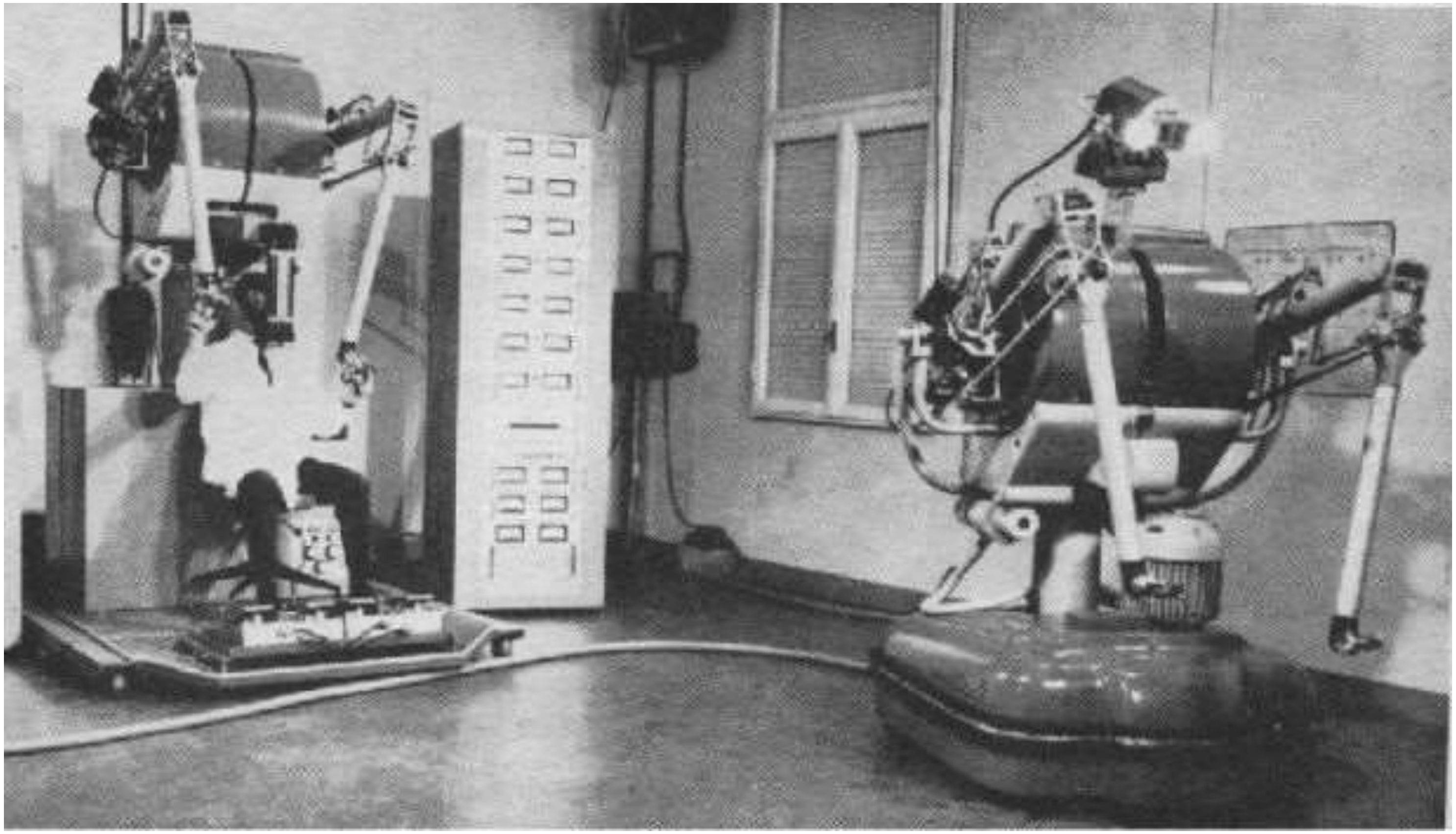
  Yes-Man Teleoperator

  Ralph Mosher G.E.



# telemanipulators

- MASCOT remote servo-manipulator - 1958
  Carlo Mancini et al.



# packaging industry

- Delta – parallel kinematics robot
  invented by Prof. Clavel at EPFL in 1985 – initially commercialized by Demaurex SA

# academic background

- EPFL, Switzerland
  Department of Micro Engineering

# academic background

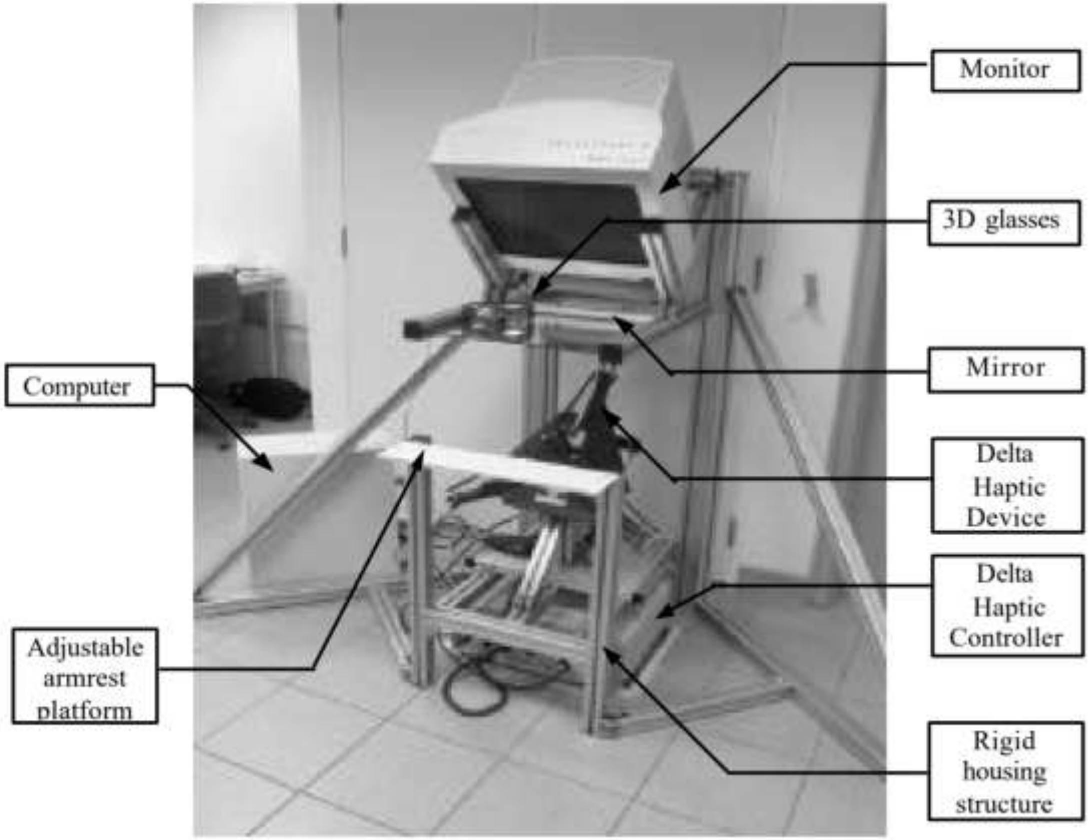
- Stanford University, USA
  Department of Computer Science



## first product

### providing NUS with a Delta Haptic Device

- the beginning of a commercial activity



# company

- company founded in 2001
  privately owned – 4 founders

Force Dimension LLC

Baur SA (since 1948)

**R&D facilities and headquarters**

- Nyon VD, Switzerland

**manufacturing site**

- Saint-Aubin NE, Switzerland

# core business

## product design and development

- customer requirements assessment
- dedicated haptic hardware design
- dedicated software interface design
- prototyping and verification

## industrialization and manufacturing

- selection of manufacturing processes
- compatibility with required volumes
- quality control to customer requirements
- contribution to product certification (CE, FDA)

## technology licensing

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# human perception

## challenges in using haptics

- creating the illusion of continuity

graphics rendering

**25 Hz**

haptics feedback

**1000 Hz**

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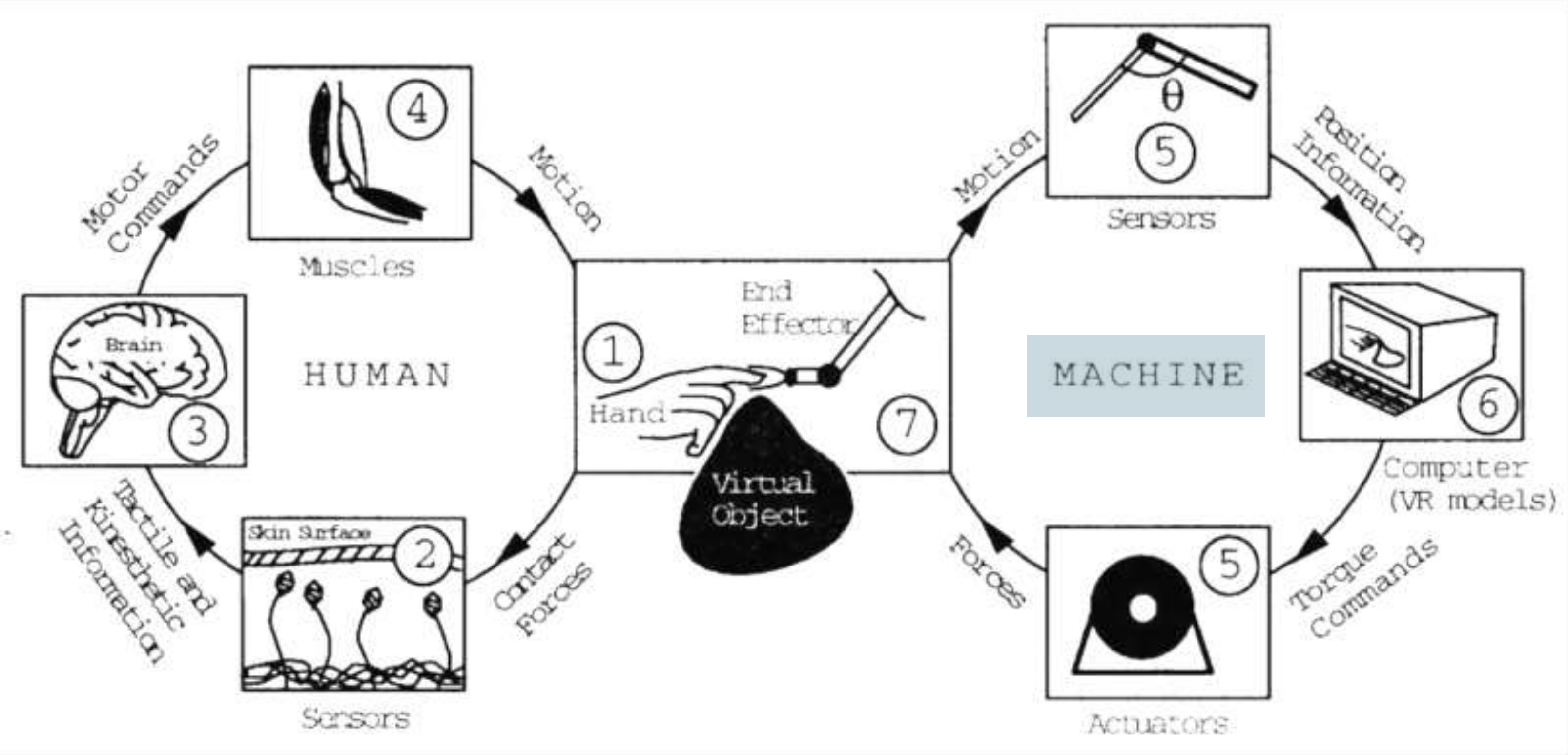
## technology

### haptic interaction control loop (impedance scheme)




Mandayam Srinivasan, MIT

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# haptic interfaces

## delta.x

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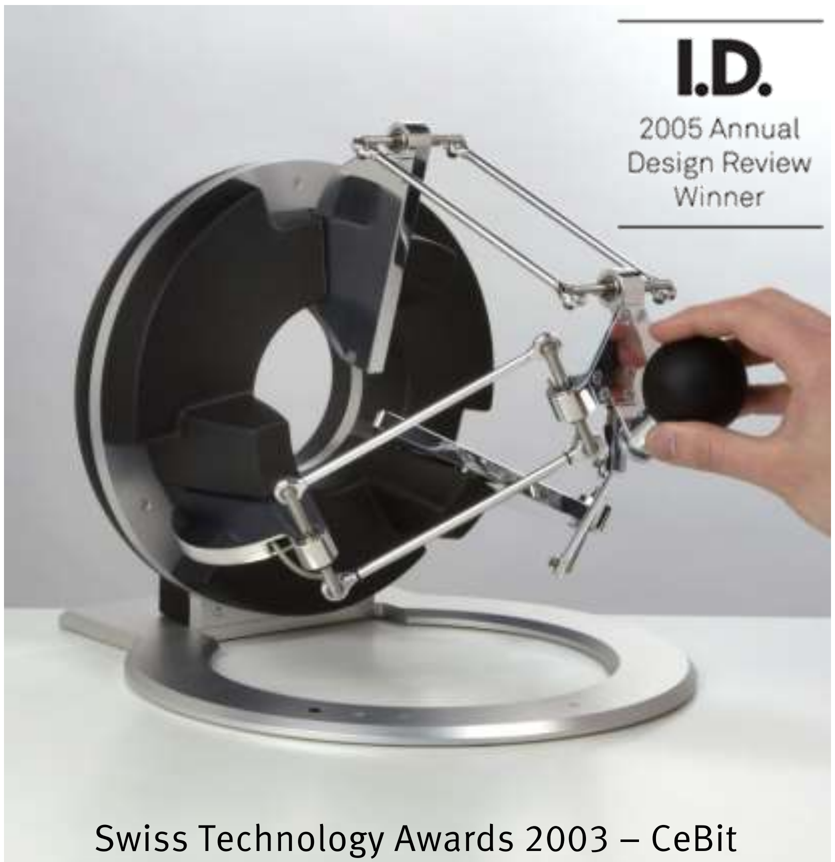
# haptic interfaces

## omega.x




omega.6

omega.3

omega.7

# medical applications

## MiroSurge system

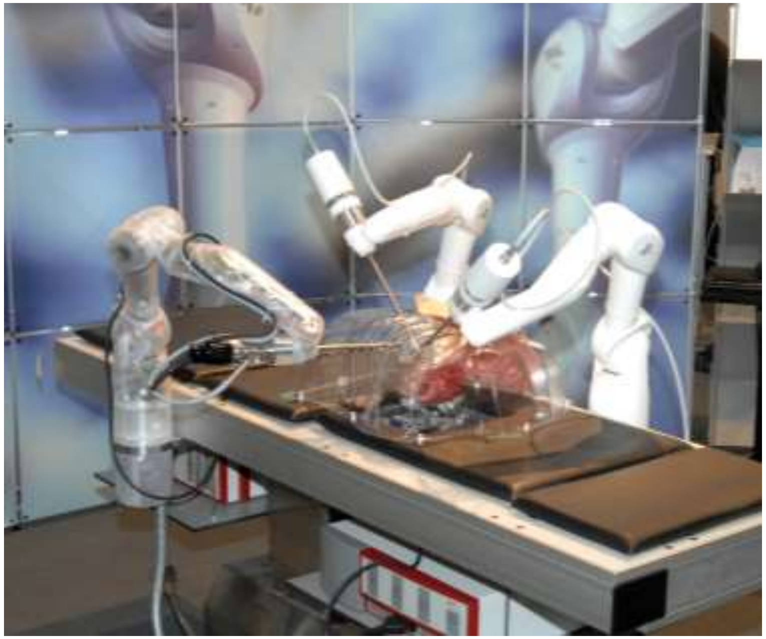
# haptic interfaces

## sigma.7

- fully active on 7 degrees of freedom
  3 translations
  3 rotations
  1 grasping

# medical applications

## MiroSurge system



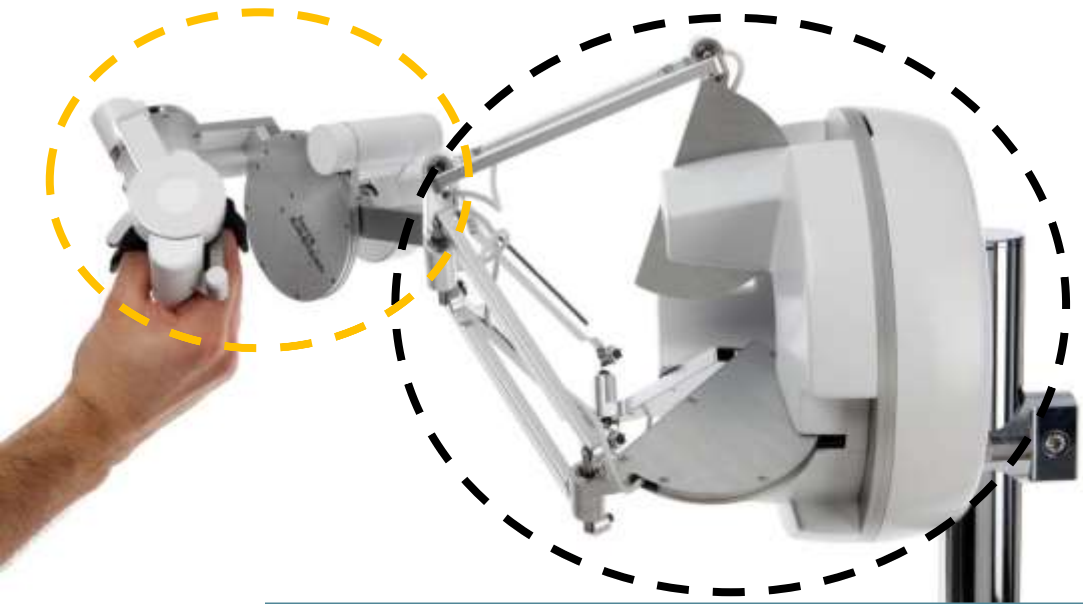
## key features

### wrist mechanism

- high dexterity
- hand-centered rotations
- decoupled from base
- customizable end-effectors

### translation base

- pure translations
- high stiffness
- high forces
- high sensitivity
- passively back-drivable
- gravity compensation
- embedded control unit
- low-level safety features
- real-time capable USB2.0
- haptics and robotics SDK
- high and low level access



# consumer market - gaming

## Falcon

Lunar Design

Novint Technologies

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# consumer market - gaming

## Falcon

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# consumer market - gaming

## Falcon

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# software

## force dimension SDK

- haptic SDK
  C/C++ libraries
  multiplatform
  supports all force dimension haptic devices
  supports the Novint Falcon
- robotic SDK
  superset of the haptic SDK
  provides position control
  provides trajectory control
- extensible
  fully compatible with CHAI3D

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# software

## CHAI3D

- simulation framework
  C++ libraries
  open source
  multi-platform
  multi-device
- capabilities
  3D graphic rendering (OpenGL)
  haptic force simulation
  modeling of dynamic bodies
  real-time deformable structures
  volumetric models (medical imaging)
  force control systems
- industry and academic partners
  Force Dimension
  Hansen Medical
  Stanford University
  EPFL

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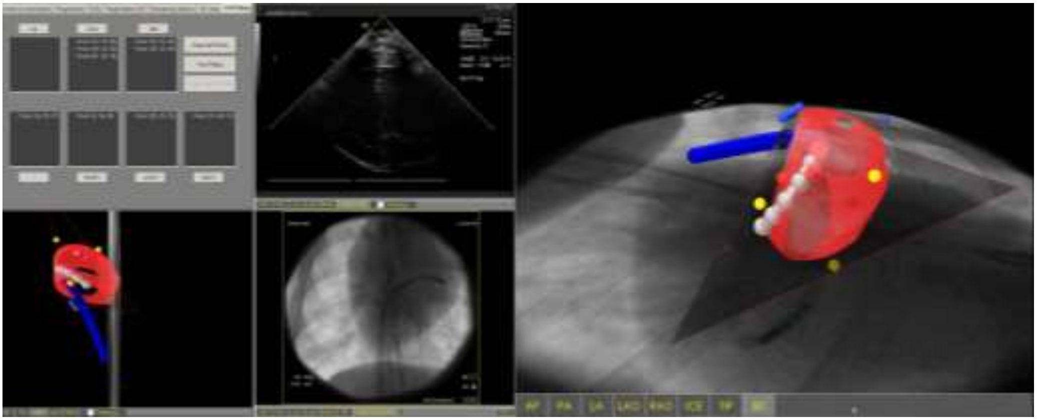
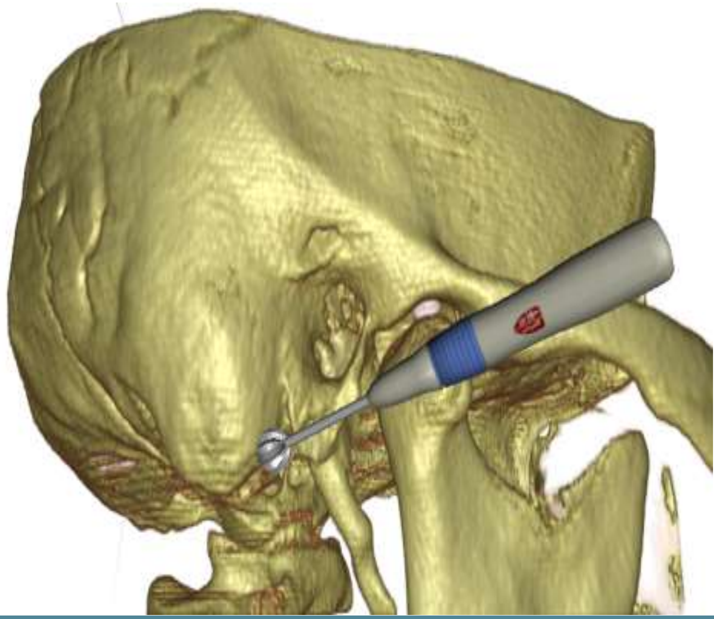
# software

## www.CHAI3D.org – application design

- haptic interface design
  high resolution haptic rendering
  fusion between sensor data (force sensor) and preoperative imaging models
  robot control and interfacing
- medical imaging
  volumetric data rendering
  imaging data (ultrasound, CT, MRI, DICOM)
  3D modeling of rigid and deformable structures





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## medical simulation

### Ultrasound ScanTrainer


MedaPhor

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# simulation

## advanced cockpit design

- tactile interface design
  gear shifts
  buttons
  knobs
  levers
  kinematics drawers
- quantitative parameter specification
  human metrics determination
  user evaluation
  on-line modification
  reduce number of design iterations
- virtual prototyping

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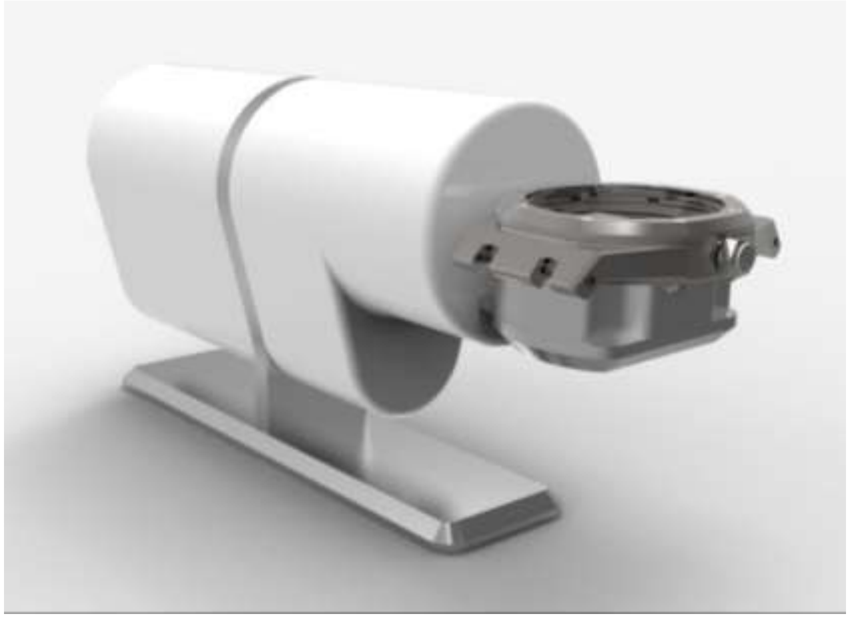
# simulation

## ChronoSim : watch interaction simulator



AUDEMARS PIGUET
Le Brassus

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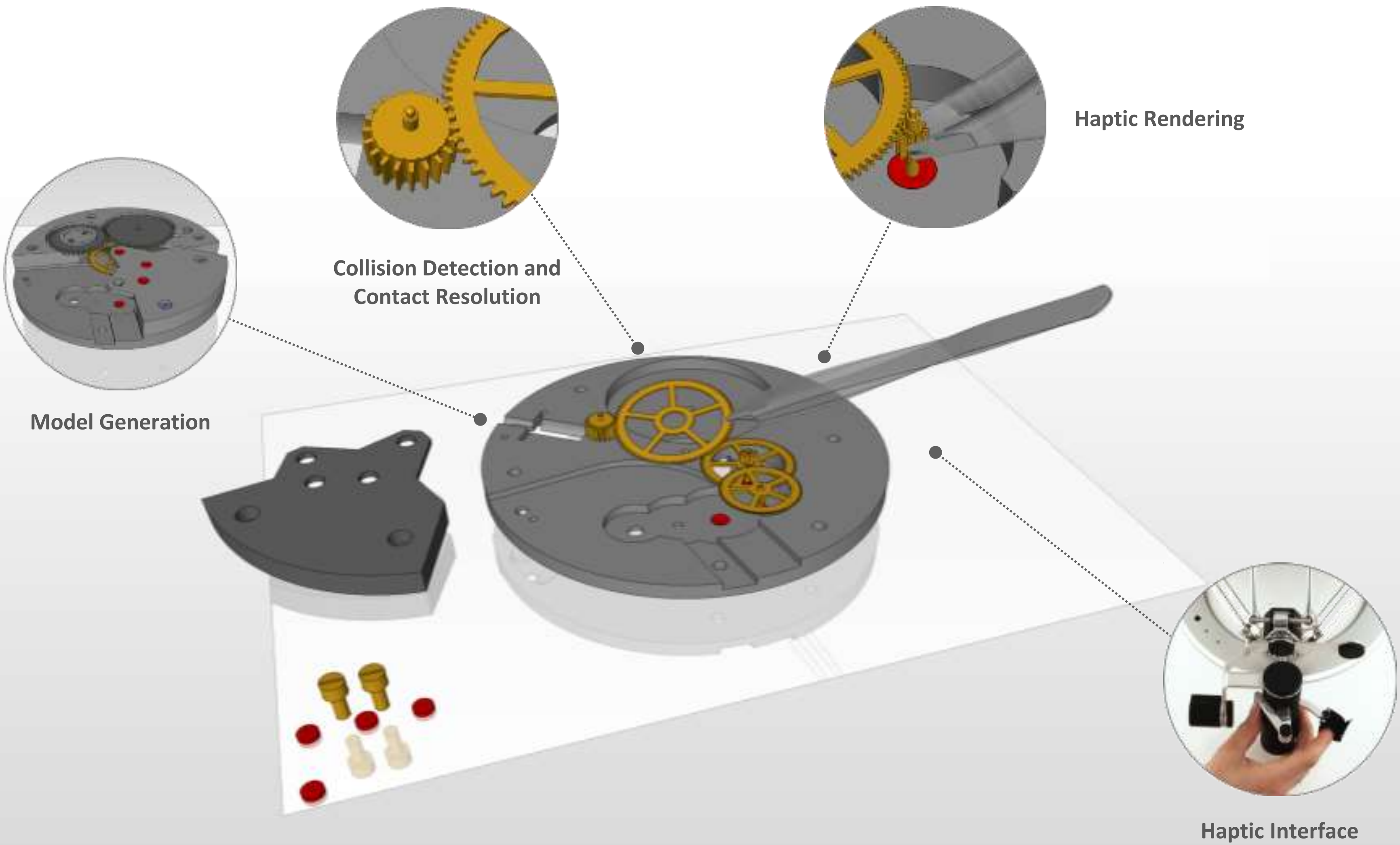
# simulation

## virtual assembly


Haptic Rendering
Collision Detection and
Contact Resolution
Model Generation
Haptic Interface

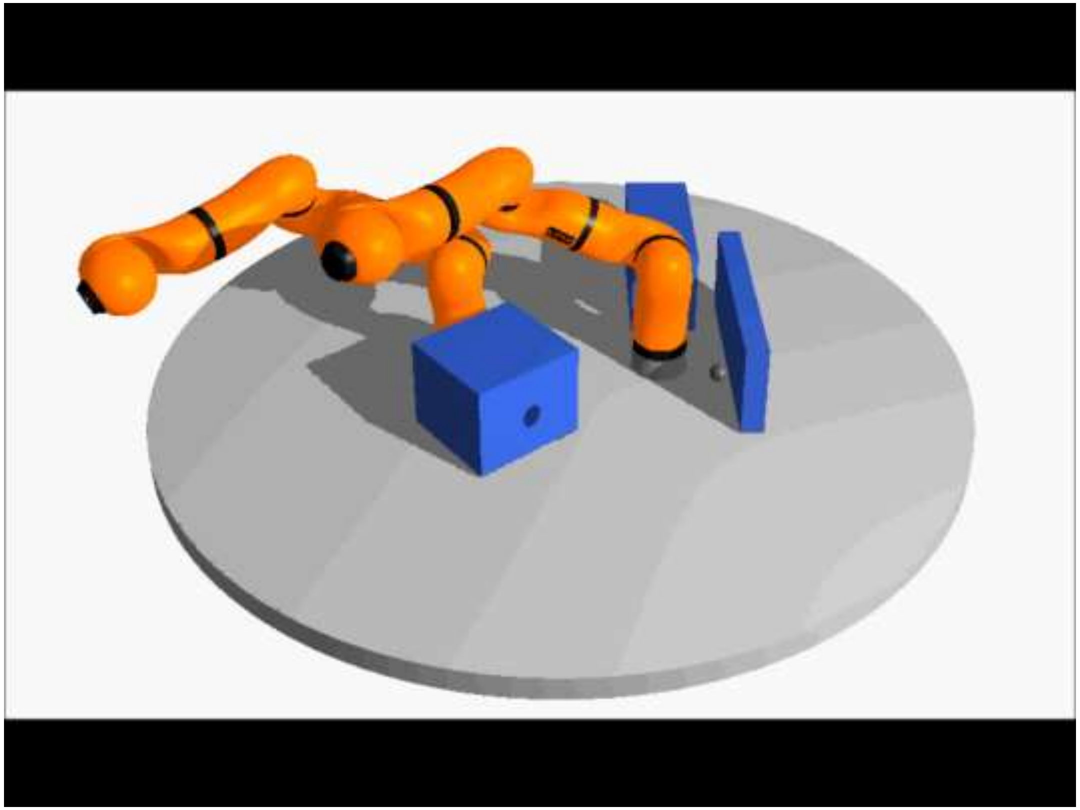
# simulation

## virtual assembly

- highly immersive haptic-graphic virtual environment
- assembly plan generation and validation
- assembly trajectory optimization
  real-time 3D collision rendering (tool-object, object-object)
  haptic constraints / guides
- accessibility validation
  manufacturing
  maintenance
- tooling selection and optimization
- task annotation in 3D
- workplace modeling

## simulation

### virtual KUKA LWR robot teleoperation



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VIRTUALINCISION

# medical applications

## miniaturized robot for general surgery abdominal procedures

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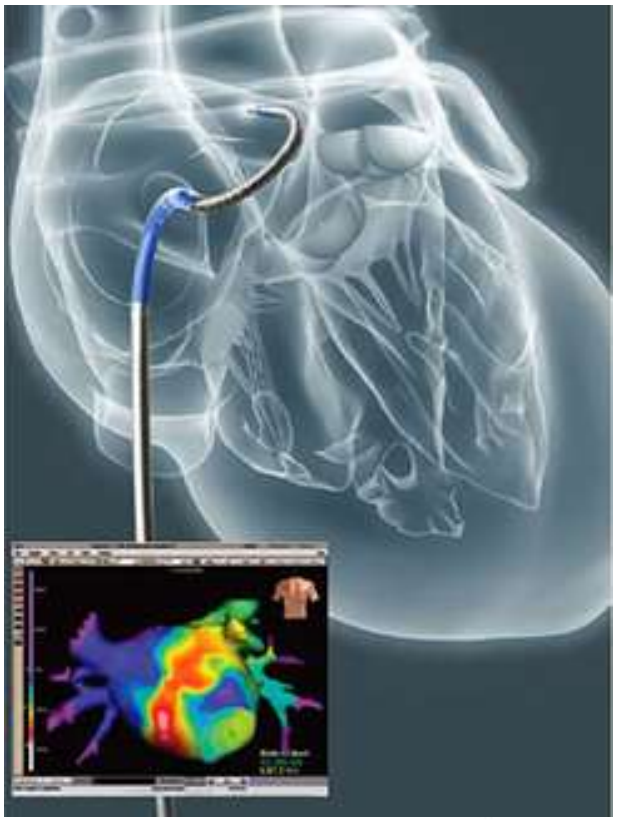
# medical application

## radiofrequency catheter ablation



hansen MEDICAL
The Global Leader in Flexible Robotics

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## medical application

### radiofrequency catheter ablation

hansen® MEDICAL
The Global Leader in Flexible Robotics

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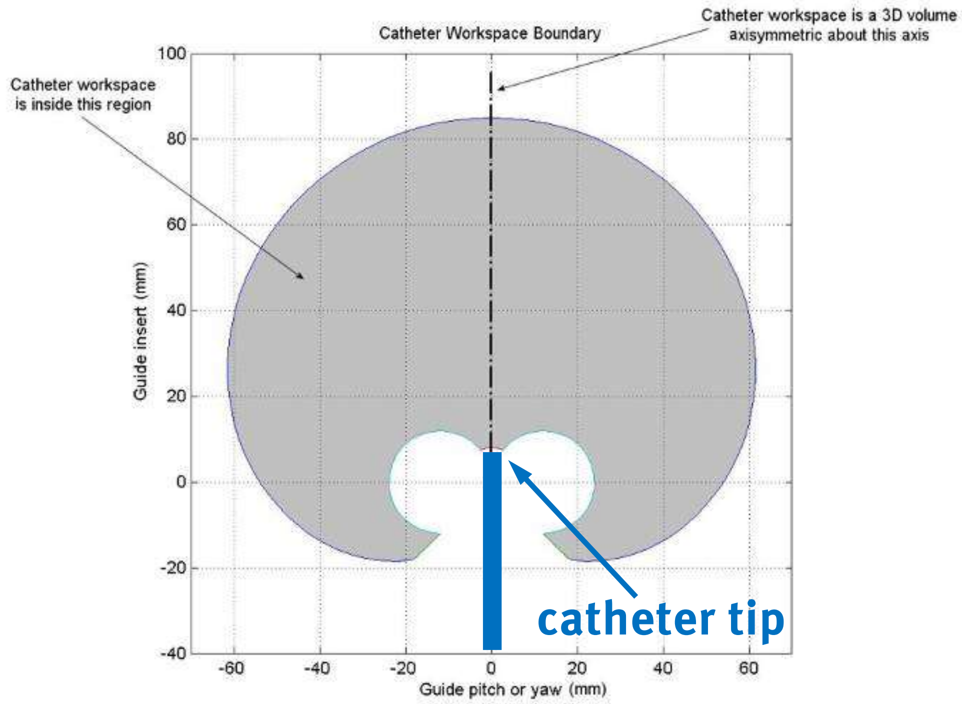
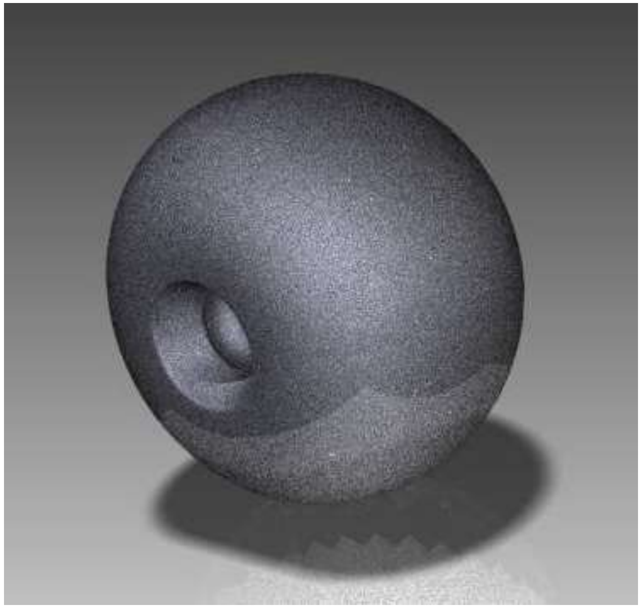
# kinesthetic feedback

**force feedback is essentially used to**

- enforce workspace limits on the guide
- re-center device when not actively driving

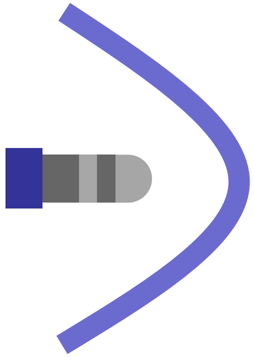


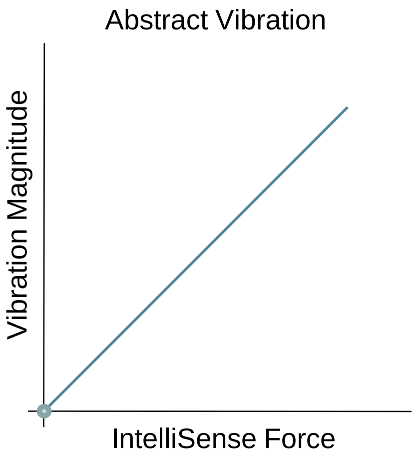



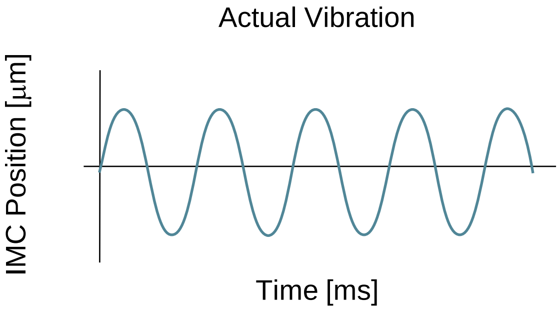
## sensed force vibration feedback

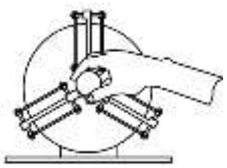
### Haptics Feedack

- measured force causes master device vibration
- vibration amplitude and frequency increase as measured IntelliSense force increases





*Movement for effect.*
*This vibration is visually imperceptible.*
*Users feel “buzzing”*

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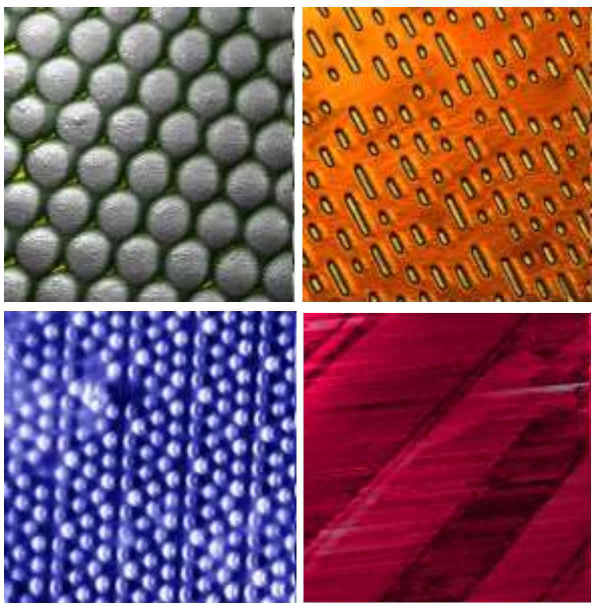
# aerospace (NASA)

## operating in critical environments

- bi-manual control of surgical robot
  with force-feedback
  in micro-gravity or moving contexts
- dynamic gravity compensation
  sensors measure environment gravity
  haptic device stabilizes gesture
- tested in micro-gravity
  using parabolic flights aboard NASA’s C9

# nanomanipulation

## AFM technology



© nanosurf

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# nanomanipulation of carbon nanotubes

## haptic user interface

- direct control and feedback
  real-time interaction
  no visual feedback is required

3D movements
scaled DOWN →

← atomic forces
scaled UP

Haptic User Interface

AFM device

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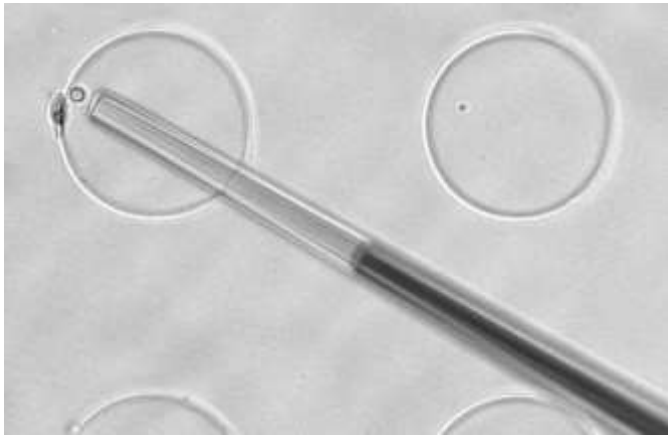
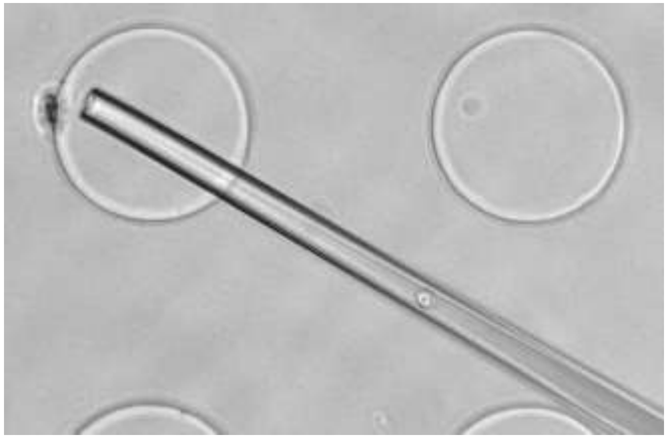
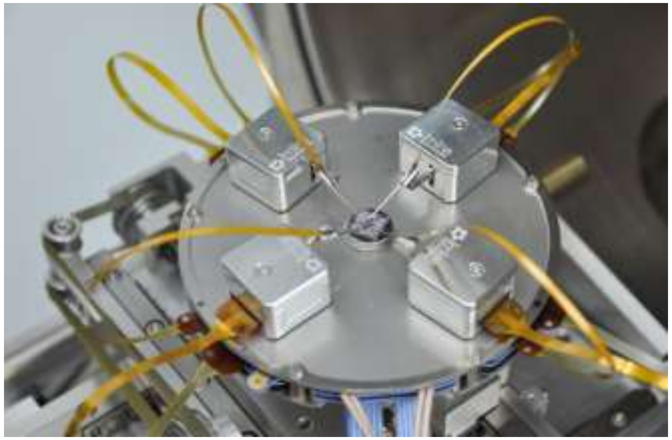
# pharmaceutics and microbiology







imina technologies

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# industrial applications

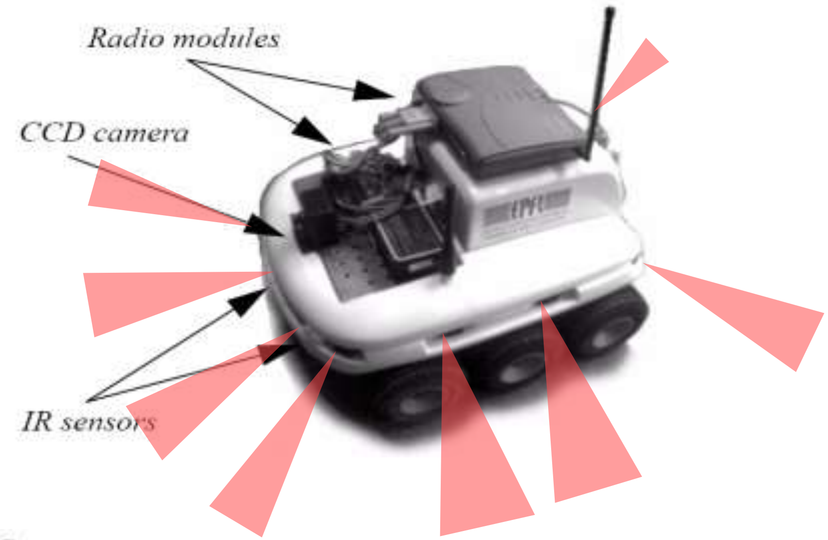
## Vulcan Tactile System VTS

VULCAN ENGINEERING CO.

# teleoperation

## mobile robot driving

Baur SA

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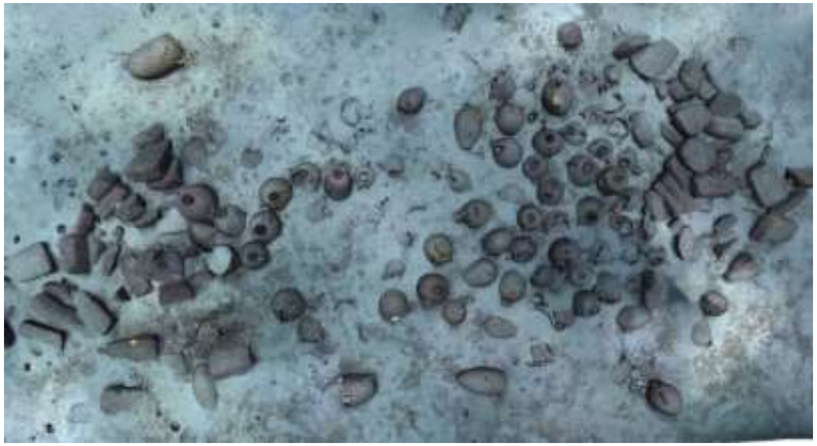
# teleoperation

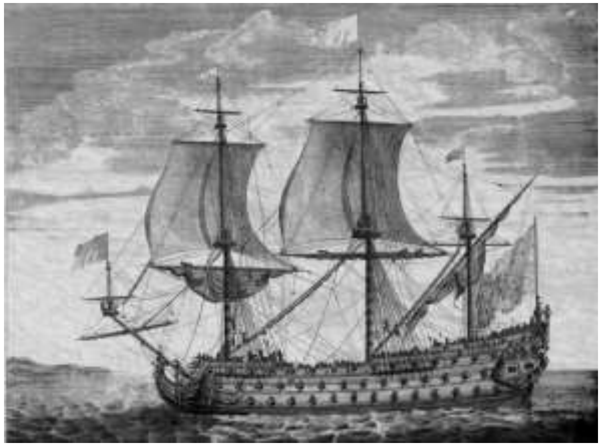
## Twente/Canberra teleoperation (10’268 km)

- remote operation of flying vehicle
  pilot is in the Netherlands
  vehicle is in Australia
- obstacles are rendered as forces
  calculated using optical flow from on-board camera
  sensed directly in pilot control hand
  even outside of vehicle camera FOV
- network delays are managed
  vehicle velocity is limited to avoid collision
  vehicle autonomously avoids collisions

# underwater robotics

## shipwreck of “La Lune” - flagship of Louis XIV  (1664)





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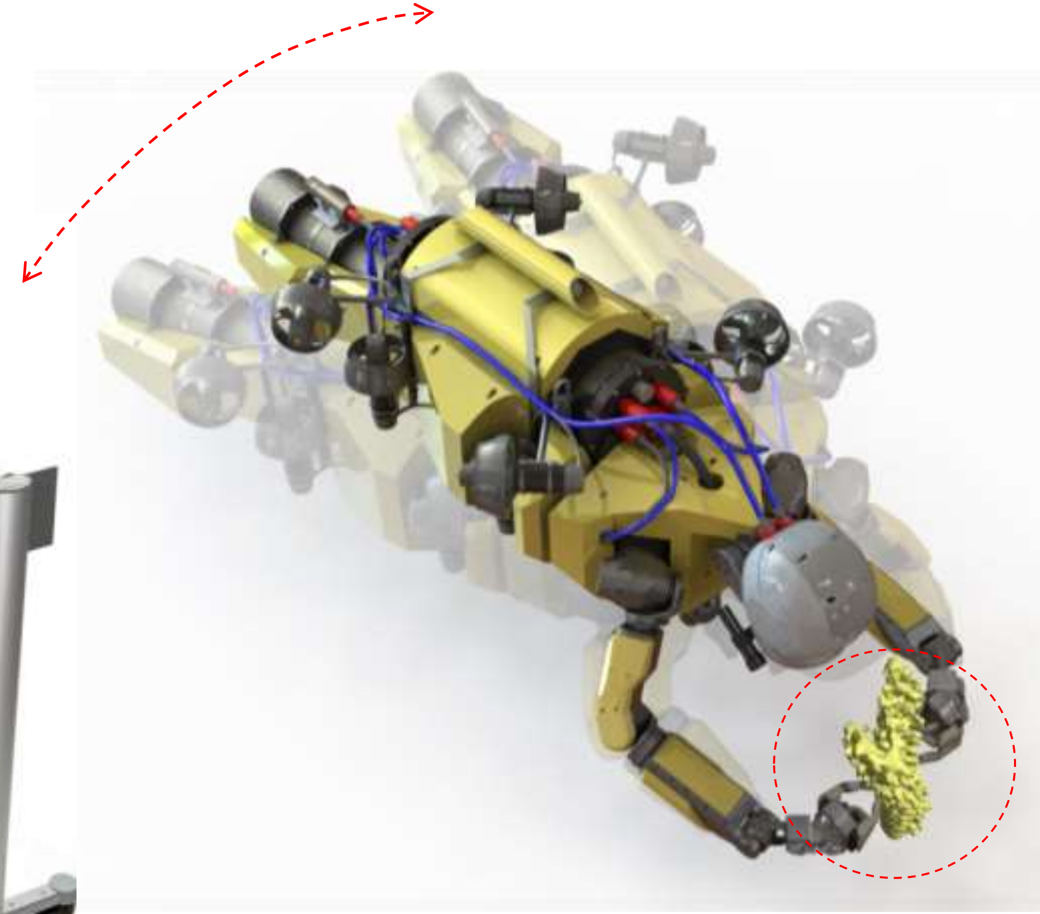
# underwater robotics

DRASSM - Département des Recherches Archéologiques Subaquatiques et Sous-marines

## underwater robotics

**ocean one**



dynamic task and
posture coordination

Stanford University - KAUST - MEKA - Google - DRASMM - Force Dimension

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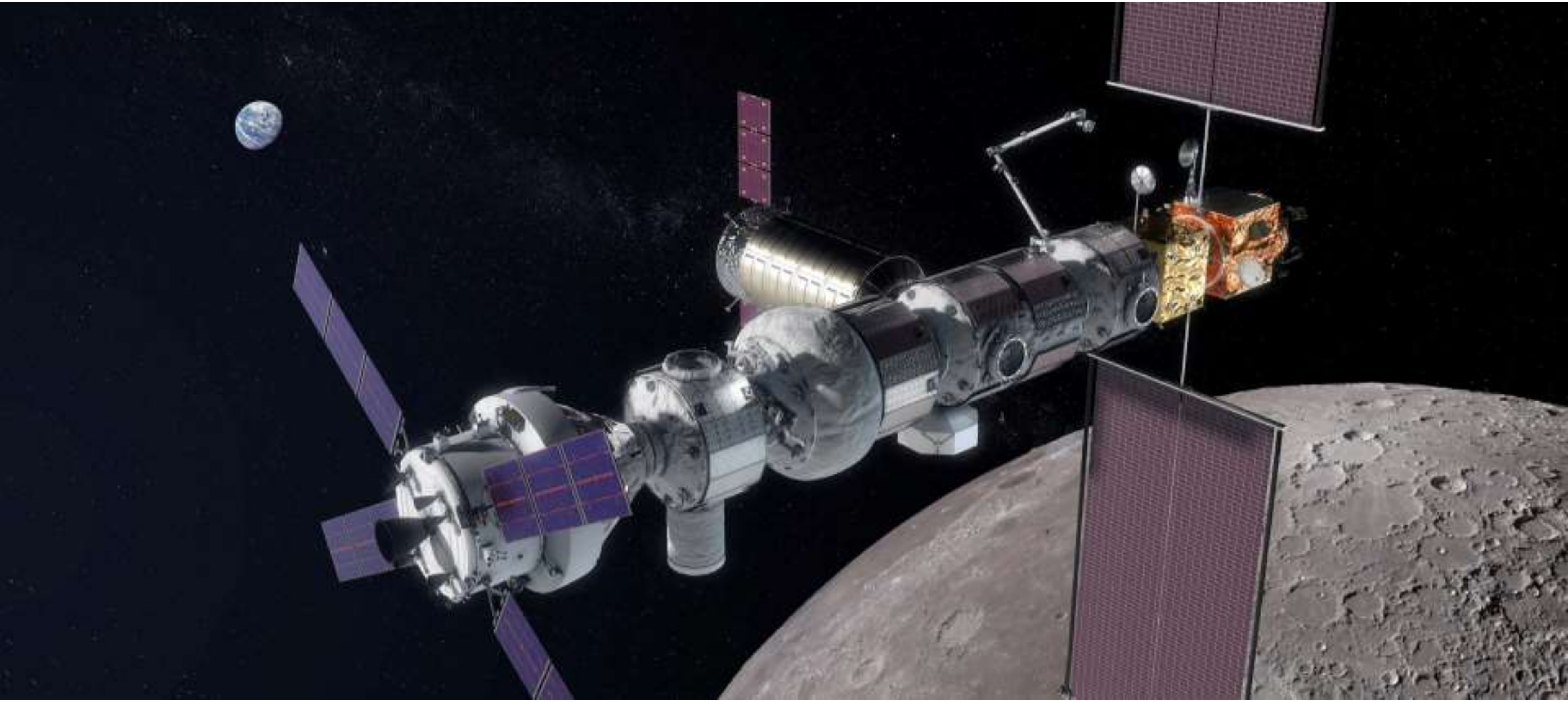
# robotics

## advantages of haptic robot control

- remote operation
  hostile / inaccessible environment
  better ergonomics / less fatigue
- force scaling
  more sensitivity / strength
- geometrical scaling
  more precision / motion range
- “feel” the environment
  feel tool interaction forces from F/T sensor
  feel obstacles before actual collisions
- “feel” robot limitations
  tracking errors / dynamics
  workspace boundaries
- augmented reality
  display additional computer generated data
- add/remove haptic information
  virtual fixtures / constraints / tunnels
  exclusion regions
  virtual grids / attractors / trajectories
  recording/playback/edit of a hand motion
  interaction with simulated model
  vibro-tactile queues (frequency / amplitude)
  damping (tremor filtering)
  dynamic scaling (force sensor based)

# robotics

## teleoperation on ISS – ESA Analog-1



# robotics

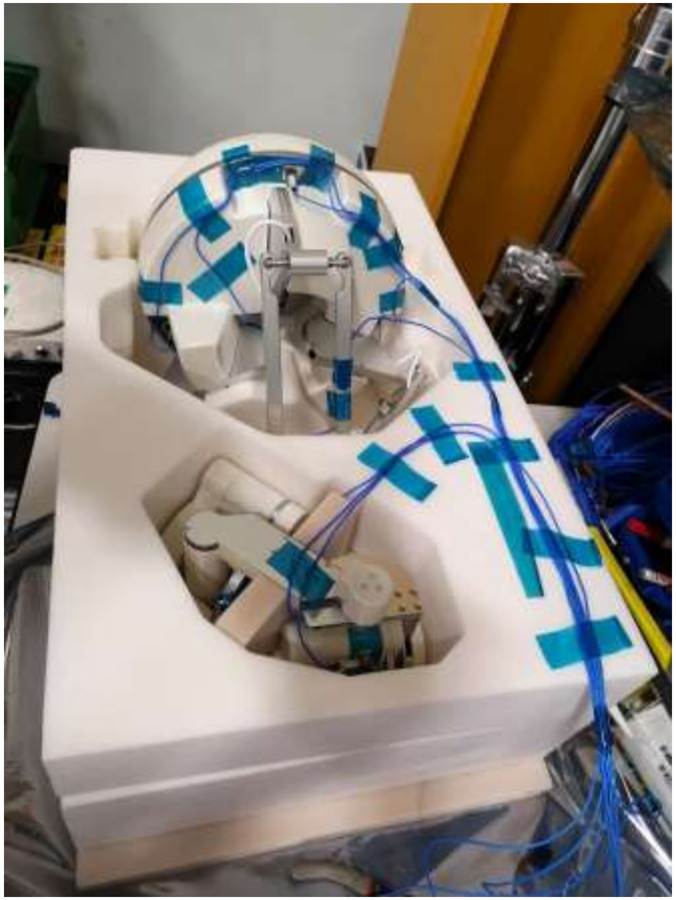
## teleoperation on ISS – training in Netherlands

## robotics

### teleoperation on ISS – starting point

## robotics

### teleoperation on ISS – launch vibration testing



## robotics

### teleoperation on ISS – all tests completed successfully

## robotics

### teleoperation on ISS – Cygnus payload

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# robotics

## teleoperation on ISS – Northrop Gruman NG-12

# Thank you!

# Time for questions & demos

## contact

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