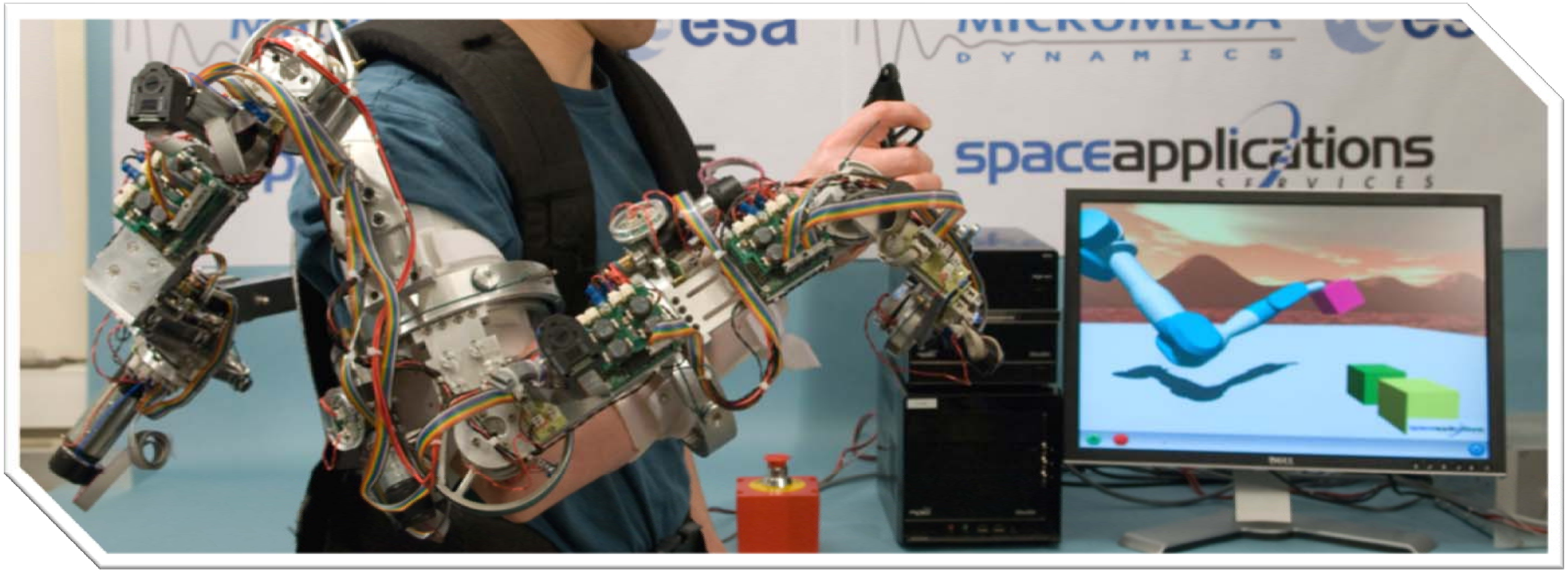
SAM
Portable Haptic Arm Exoskeleton Upgrade Technologies And New Application Fields



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A Few Words of Acknowledgement…

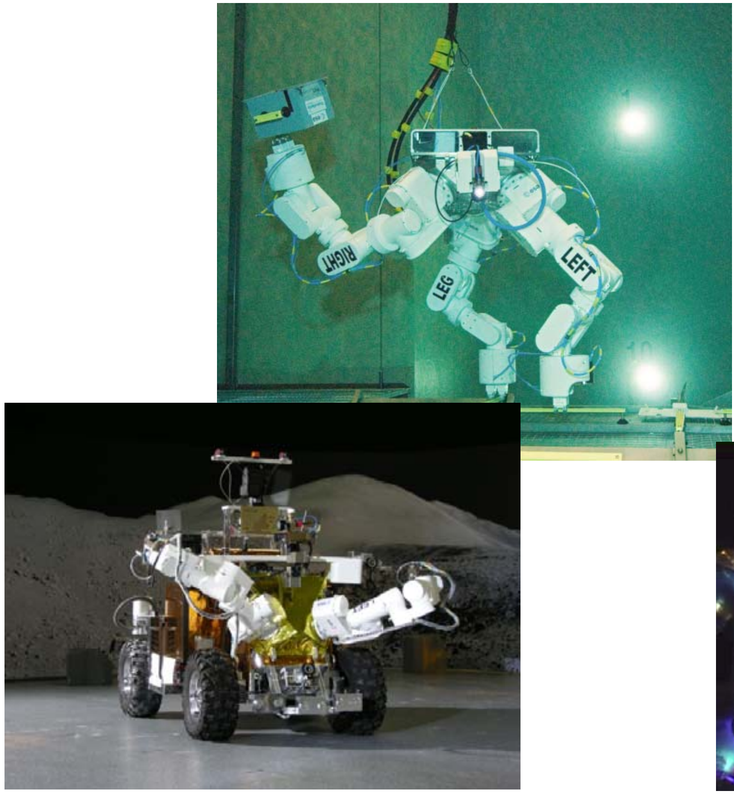
SAM is a derived product from the **EXOSTATION** project, an ESA project funded in the framework of the Technology Research Program entitled : *Control Stations for new Space A & R Applications,*

in which cooperated the following partners...

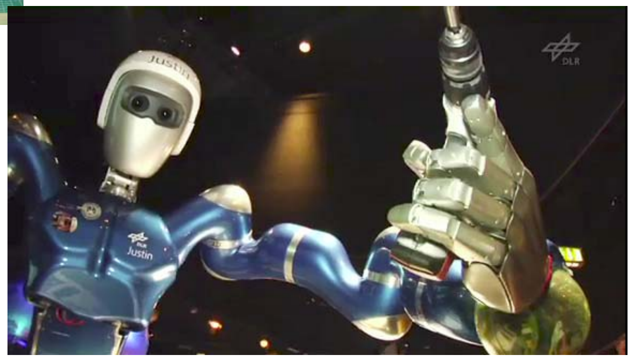
Prime Contractor :

Sub Contractors :

Space Technology Trends: Anthropomorphic Slave Robots



EUROBOT Wet model and EGP
(ESA)



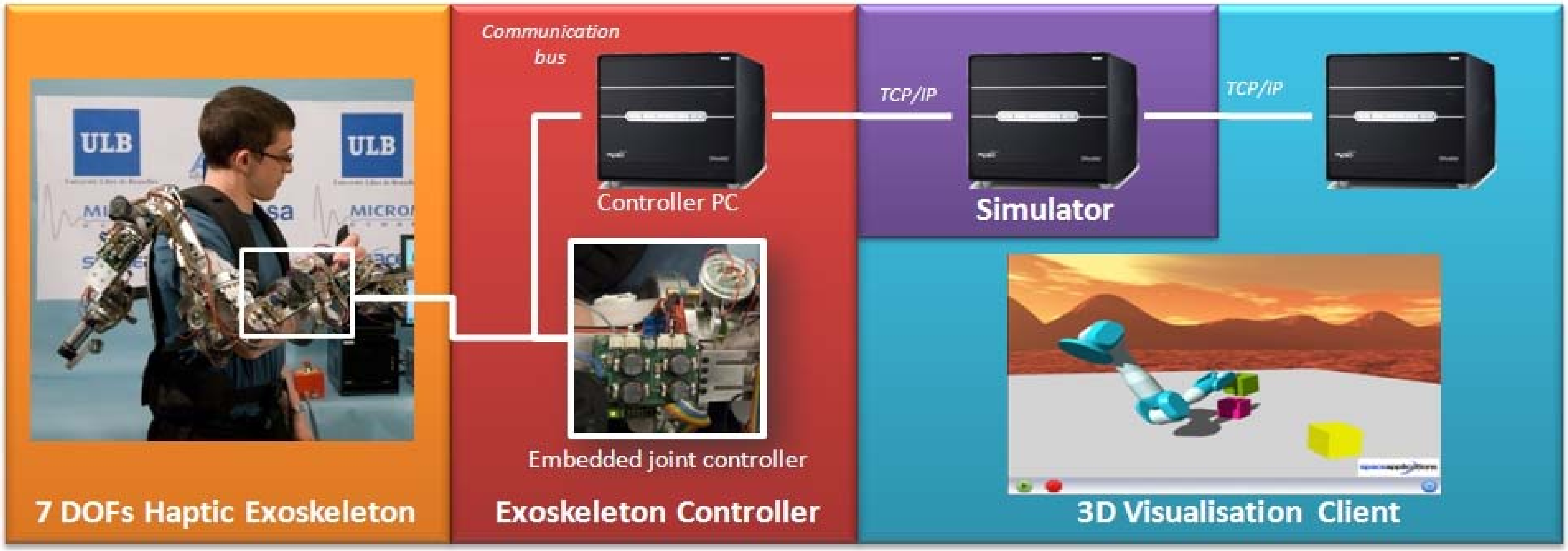
JUSTIN
(DLR)

ROBONAUT(R2 and Centaur)
(NASA)

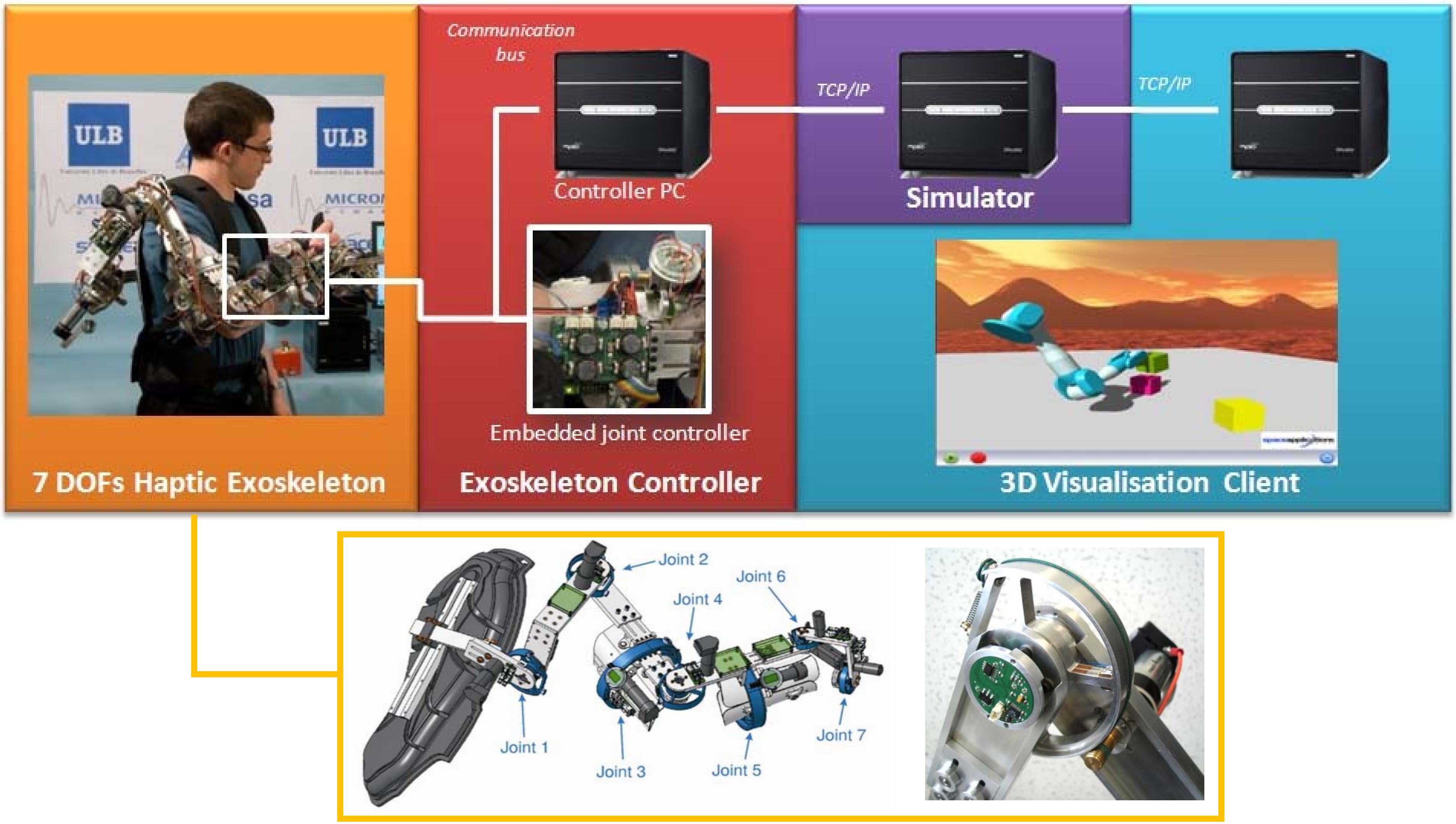
- EVA support or replacement
  - Costly, risky, resources demanding (on-ground and on-board)
  - Stressing and tiring for crew

System Overview: EXOSTATION's goal

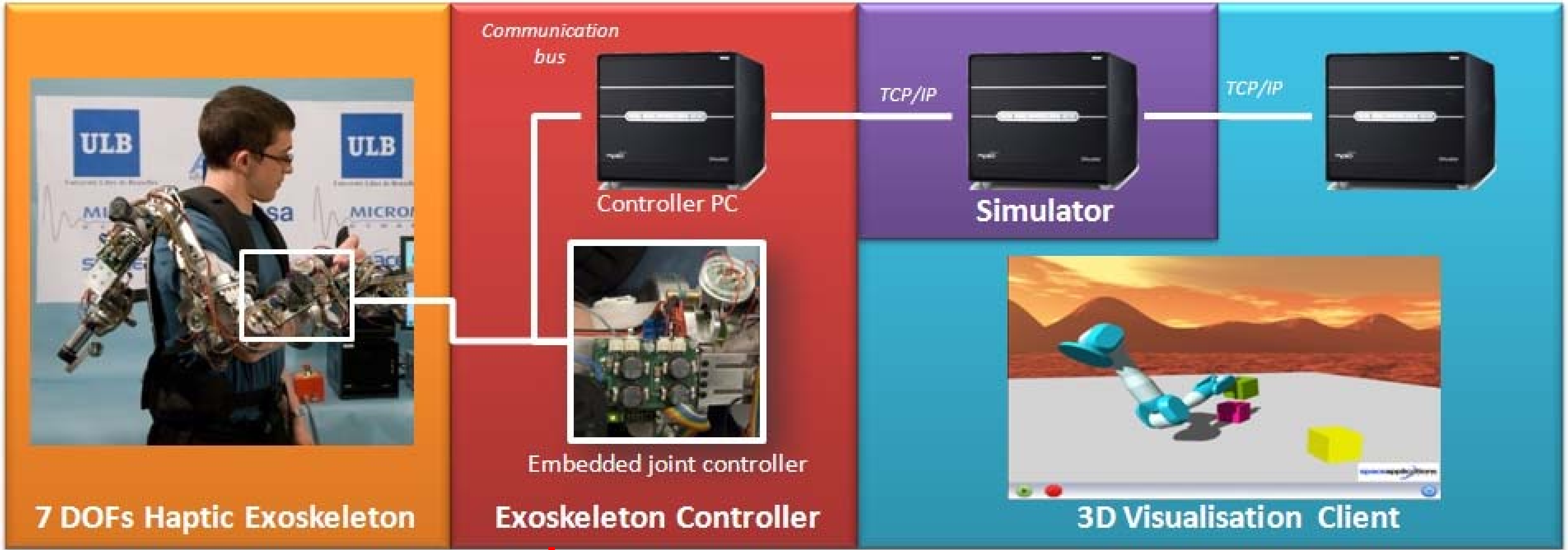
Building a complete haptic control station which allows the operator wearing an exoskeleton-based haptic interface for the human arm to remotely control a virtual slave robot.



System Overview

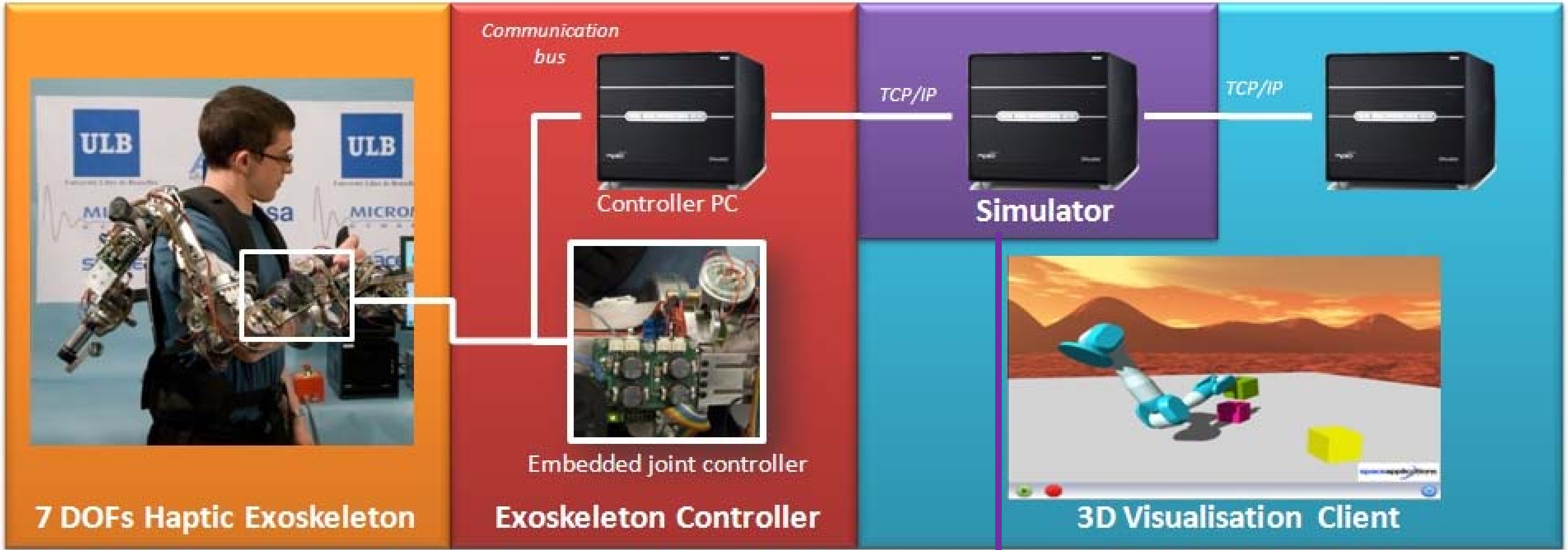


System Overview



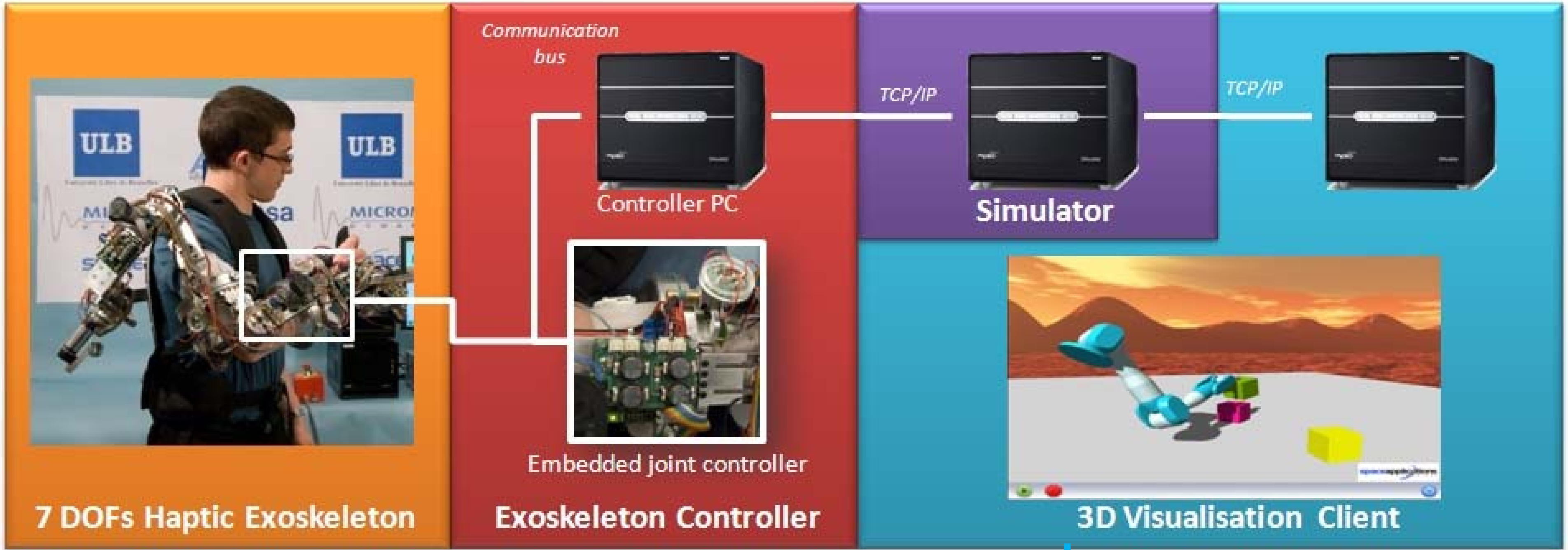
- Power amplification
- Sensors conditioning
- Communications between boards and main controller
- Haptic control loops
- Haptic rate and synchronisation

System Overview



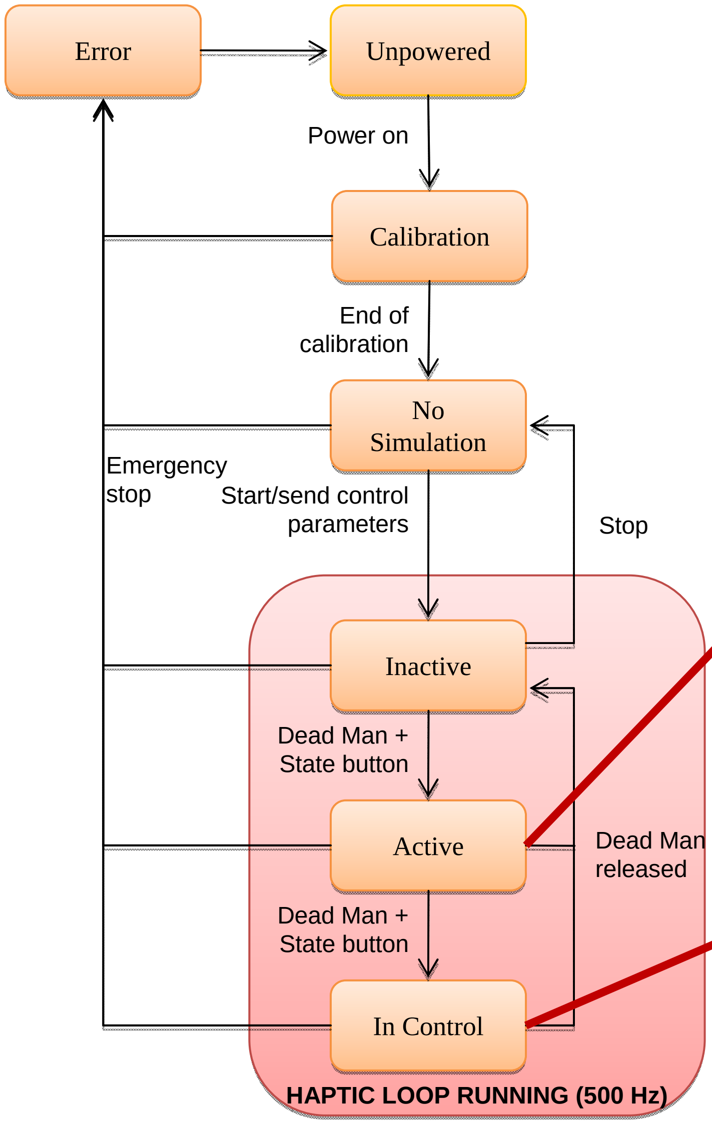
- Simulates a 7-DOF anthropomorphic robot cinematically equivalent to the master and its interaction with a virtual environment
- Based on ODE
- Scripting technology to quickly design virtual environments and modify control strategies

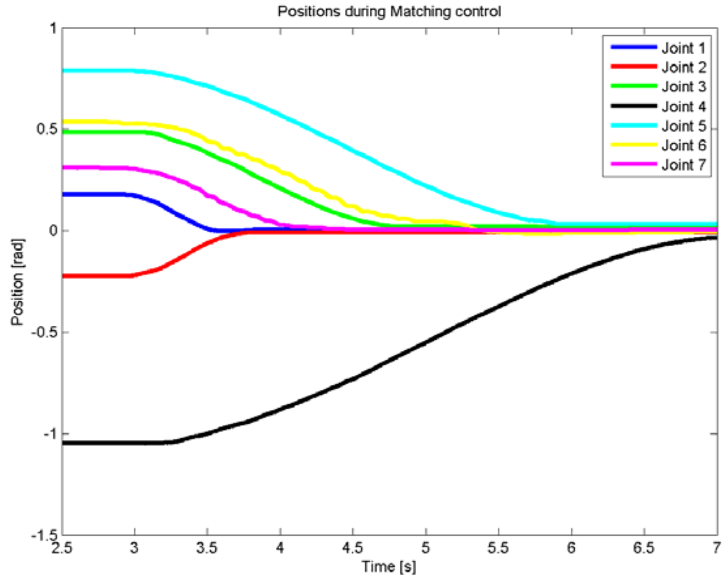
System Overview

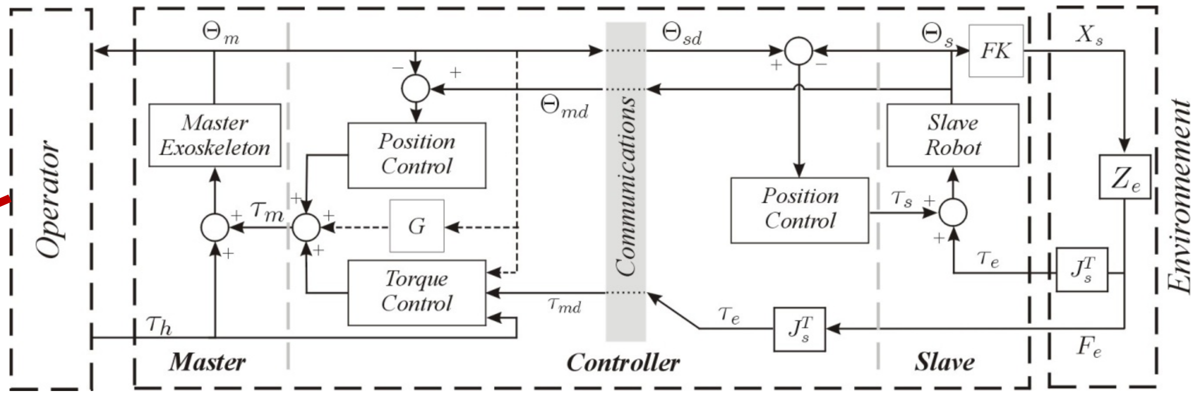


- Visualisation of the virtual world
- Supports various states of the system

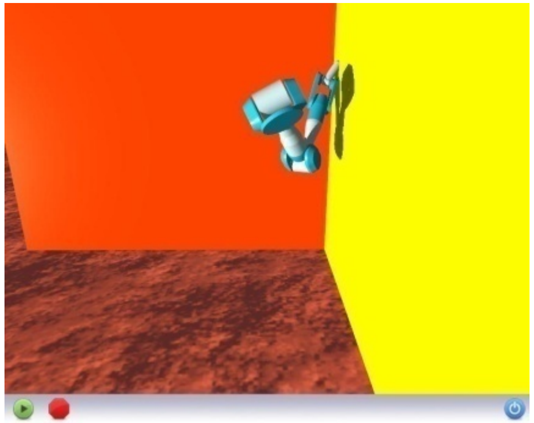
State Machine and Control



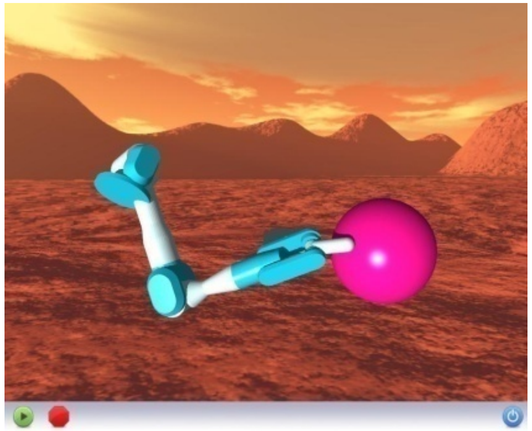




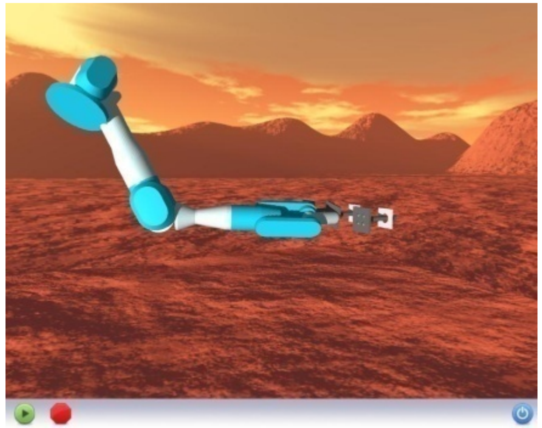
EXOSTATION Scenarios



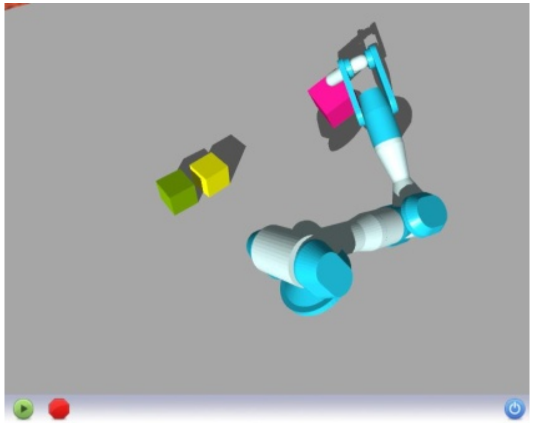
Wall Tapping

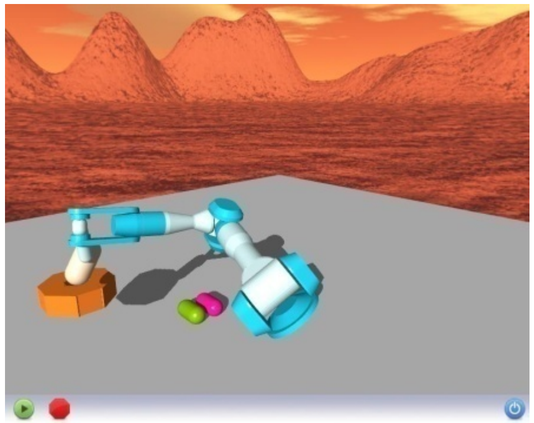


Shape Screening

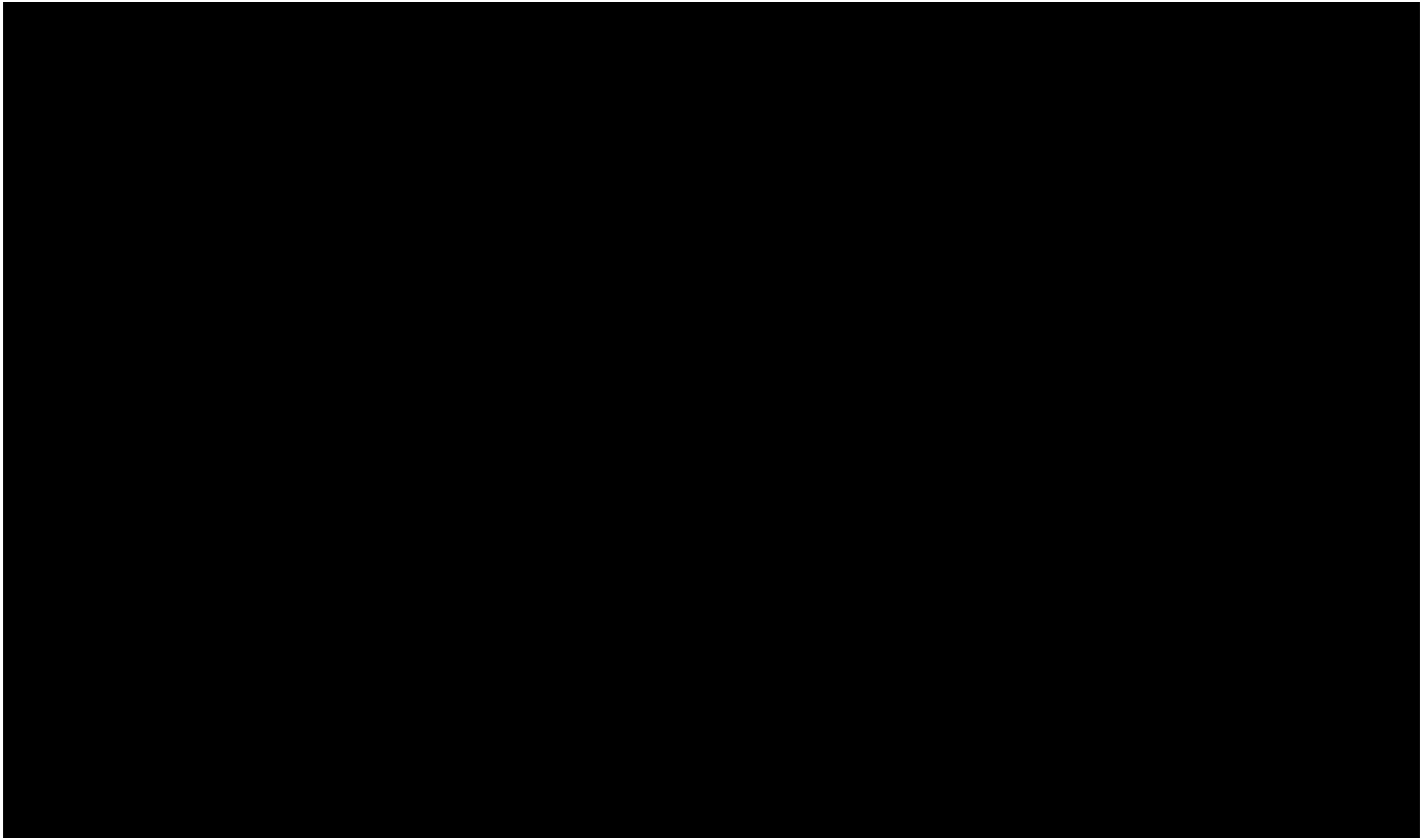


Constraint motion on the robot
(screwing, sliding)

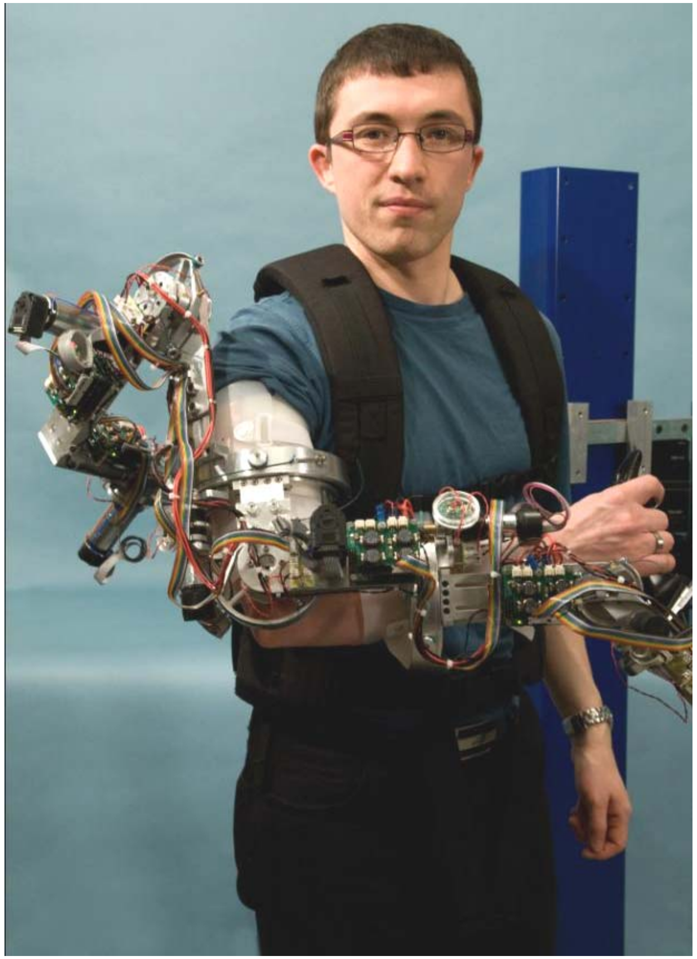




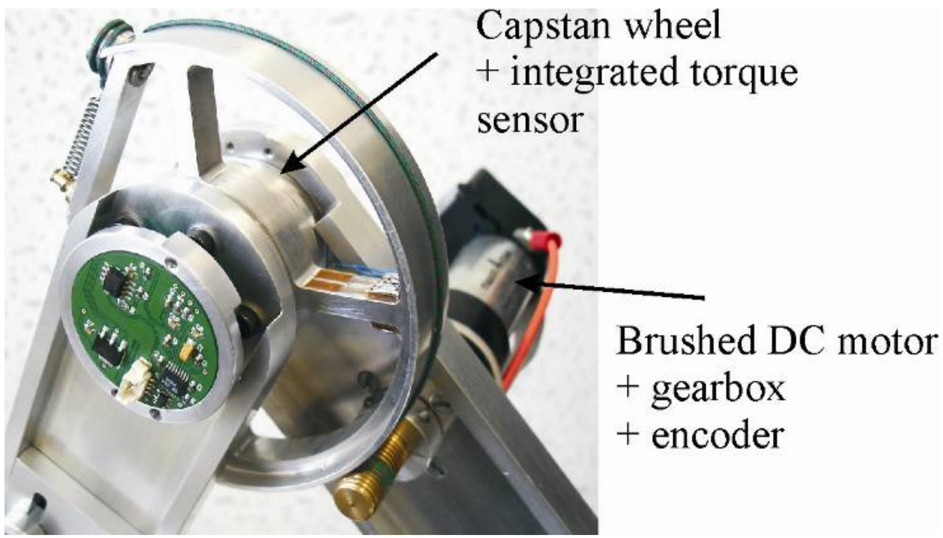
Manipulation tasks



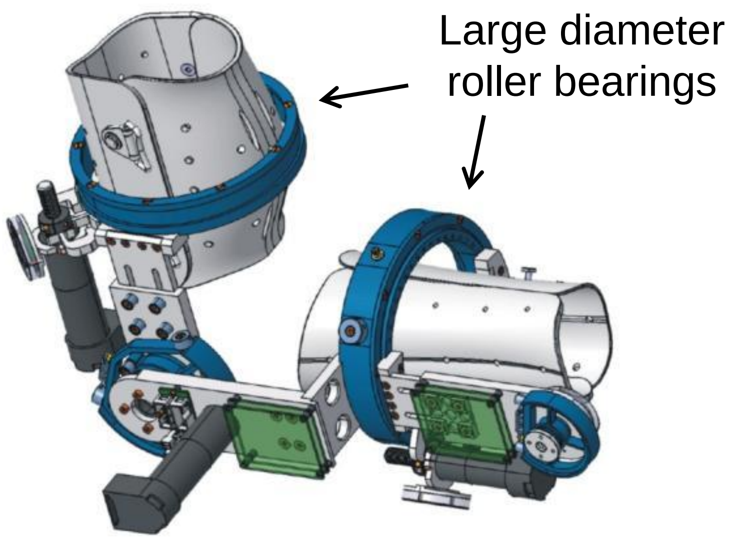
SAM Exoskeleton



- 7 actuated DOF, 6 adjustments sliders
- Compact on-joint actuation with integrated position and torque sensor
- 1/20th of the human torque capabilities (10 to 1 Nm, shoulder to wrist)
- Aluminum structure with ergonomic fixations
- On board electronics (conditioning and amplification)
- Weight of 7 kg



Improvements : Workspace

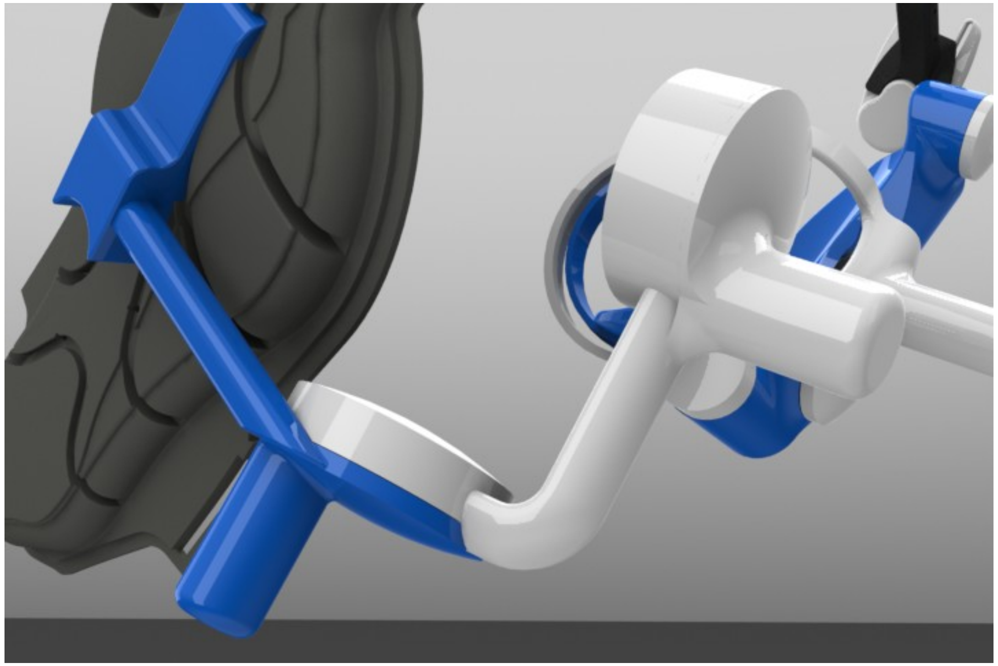


	Human Workspace	SAM Workspace	Ratio SAM/Human
Total Volume [m³]	0.65	0.38	58
Front Volume (x>0) [m³]	0.48	0.35	73

- Investigations:
  - Redesign of the backplate fixation
  - Open-circular guides

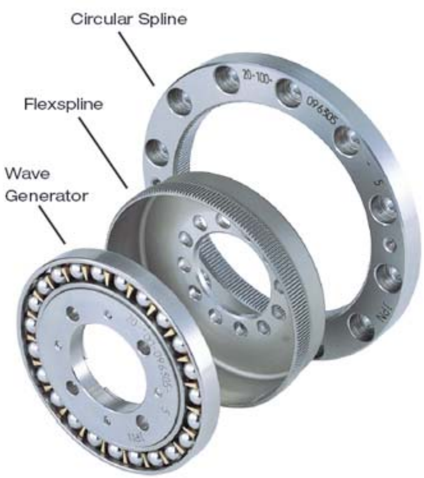
Improvements : Weight - Ergonomy

- Total current weight: 7.4 kg
  - Mechanical Structure : 3.9kg
  - Actuation: 3 kg
  - 4.5kg worn by the arm
- Internal gravity compensation



- Mechanical Structure optimization with more advanced materials and shapes (composite, polymers):
  - Rigidity
  - Manufacturing processes, assembly
  - Costs

Improvements : Robustness



- Simultaneous use of capstan and gearbox for high enough torque combined with high compactness, low friction and low backlash transmission.
- Limited use for higher torque and sensible to wear
- Deeper analysis of the capstan type reducer (cable material, wheel/shaft diameters,…)
- Other reducer technologies : e.g. Harmonic drive
  - More compact and higher output torque
  - Higher intrinsic friction, not backdrivable
  - Other control strategies : e.g. admittance control (already tested)
- Electrical robustness : data and power bus in “open-air”
  - Sensors casing protection
  - Lightweight protection shells along the structure

Terrestrial Applications: Future exoskeletons perspectives

- The advantages of a portable anthropomorphic force-feedback exoskeletons are:
  - Intuitive control of anthropomorphic robotic arms
  - Great workspace, similar to the human arm workspace
  - Multi-point contacts
  - Free body motion / transportable
  - No reaction-forces under 0G

- Potential terrestrial applications:
  - Teleoperation
  - Virtual Reality
  - Rehabilitation

Terrestrial Applications: Teleoperation

- Support of Haptic Control is very useful when one has to perform very precise manipulations. The feeling of force-feedback increases the operator's awareness of the situation (objects weight, pulling connectors, …*)*

- The main criteria that favour a haptic teleoperation system deployment are :

  ✓ **Operations requiring human skills and expertise**

  ✓ **An hostile environment** (operation field that is very dangerous for an operator to risk his life in and therefore requires to be preferably operated at distance.)

  ✓ **Very precise interventions and manipulations that do not tolerate errors** as otherwise may lead to dramatic consequences.

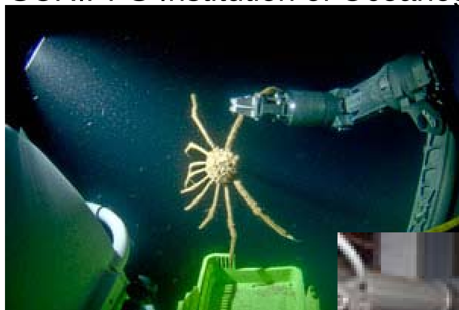
  ✓ **Emergency intervention in a de/un/structured environment** (for which intervention means and operations cannot be easily planned and deployed in advance.)

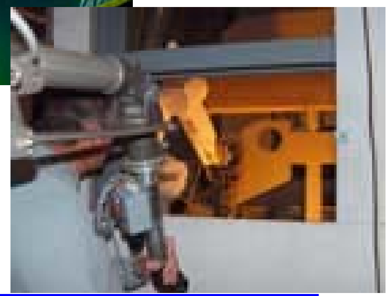
Teleoperation Application Fields

- **Intervention on CBRN** (Chemical, bacteriological, Radiological and Nuclear) crisis site
- **IEDD** (Improvised Explosive Devices Disposal) and de-mining operations
- Support to **rescue operations** after an earthquake
- **Sub-sea operations** (e.g. offshore oil rig well sealing)
- **Hazardous materials manipulations** (chemical, nuclear)
- Nuclear Infrastructure **dismantling, decontamination and waste treatment** operations


(credits: Teodor, telRob)


Monirobo

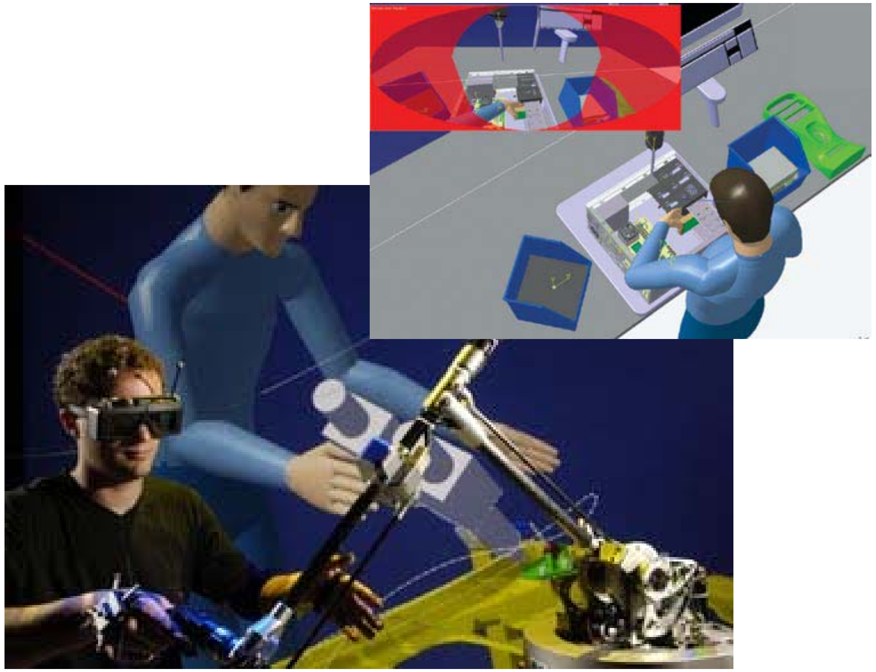
SCRIPPS Institution of Oceanography



(credits: CEA)

Terrestrial Applications: Virtual Reality

- **Virtual Training:** free body motion, multi-points contacts for better immersion
  - **FITS** ESA project to evaluate how VR and force-feedback can improve current astronaut training program
- **Virtual Assembly and Design**: virtual manikin control
- **Entertainment** (Long Term)

(credits: VRLab, Nasa)



(credits: Dassault System, haption)

Terrestrial Applications: Rehabilitation

- The patient performs repetitive task-oriented medical exercises wearing the exoskeleton:
    - User motion guidance
    - Resistive force
- Greater output torque than pure haptic needs, depending on the type of rehabilitation
- Generally associated to a set of joints

Conclusions

- EXOSTATION: demonstrator of a complete haptic control chain that shows the advantages of haptic feedback information in space teleoperation activities.
- Derived product SAM as portable haptic arm exoskeleton for terrestrial application
- Industrialisation phase for teleoperation, VR and rehabilitation terrestrial applications
- Addition of Virtual reality, augmented reality technologies

Thank you