PHYSICAL HUMAN-ROBOT INTERACTION

INTRODUCTION

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Dipartimento di INFORMATICA

GENERAL INFO

General info

- Master degree: Computer Engineering for Robotics and Smart Industry
- Year | Semester: 2nd | I
- ECTS (theory | lab): 6 (4 | 2)
- Prerequisite: Robotics (Master) and Controlli Automatici (Bachelor)
- *Suggestion: attend at the same time Advanced Control Systems*

- Classes (2022/2023)
  - Monday 11.30--13.30 (room C)
  - Thursday 16.30 - 18.30 (room I)

- Communications, Slides, Materials, etc via Moodle

General info

Physical Human-Robot Interaction is compulsory course for the Robotics systems path

- Robotics, 1^{st} year, 6 ECTS
- Computer vision, 1^{st} year, 6 ECTS
- Advanced Control Systems, 2^{nd} year, 6 ECTS
- Physical Human-Robot Interaction, 2^{nd} year, 6 ECTS

General info

SISTEMI

CONTROLLI AUTOMATICI

DYNAMIC SYSTEMS

Qualifying course

Bachelor

Master

Compulsory courses

ROBOTICS

ADVANCED CONTROL SYSTEMS

PHYSICAL HUMAN-ROBOT INTERACTION

COMPUTER VISION

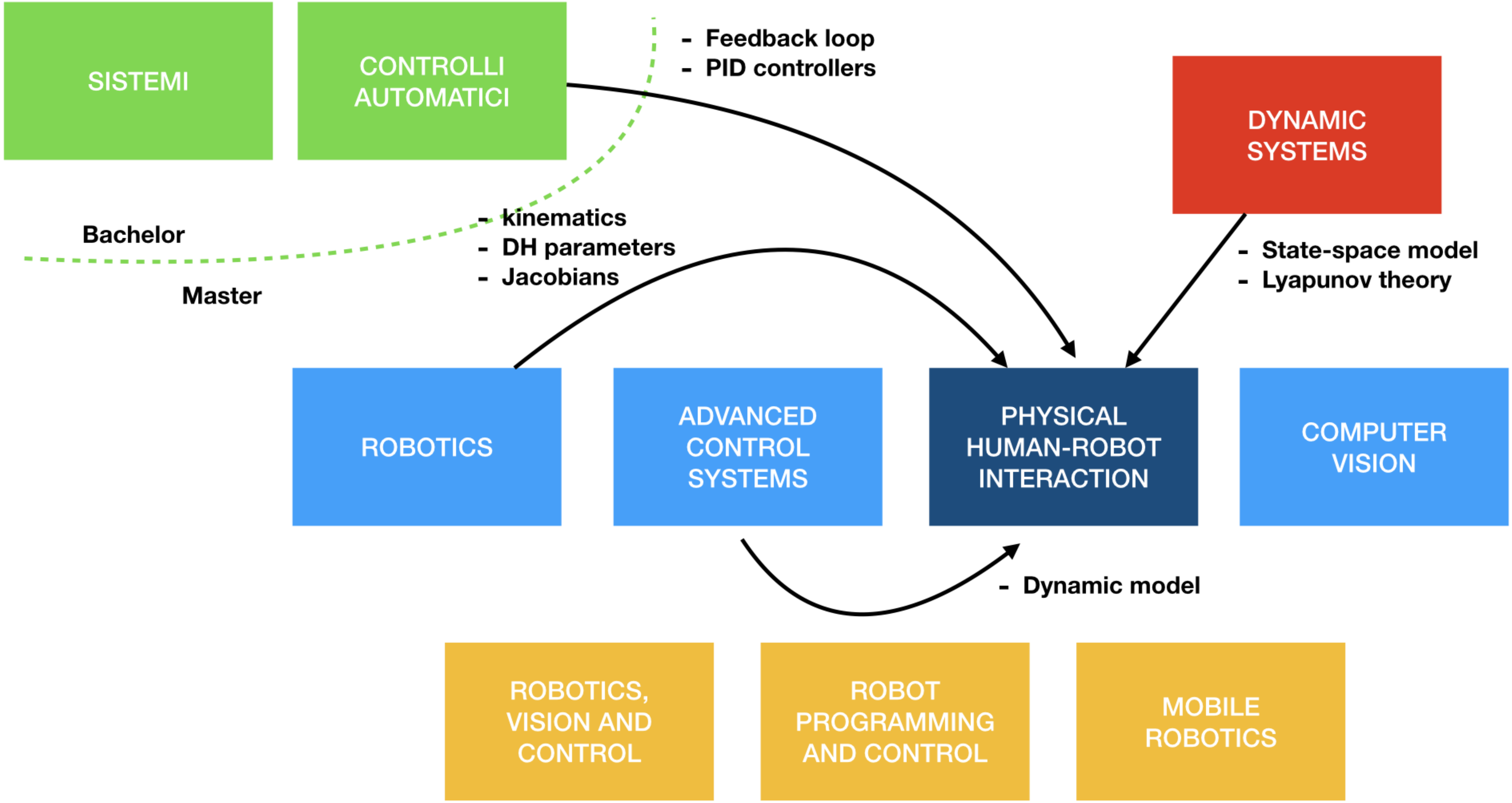
Other courses

ROBOTICS, VISION AND CONTROL

ROBOT PROGRAMMING AND CONTROL

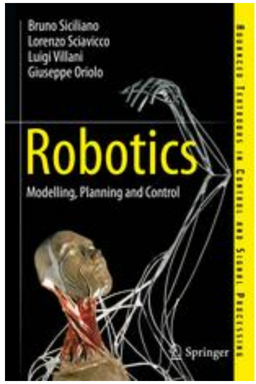
MOBILE ROBOTICS

General info

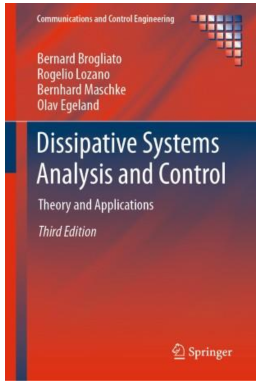


General Info

Lectures are based on



Siciliano, L. Sciavicco, L. Villani, G. Oriolo, *Robotics: Modelling, Planning and Control*, 3rd Edition, Springer, 2009



B. Brogliato, R. Lozano, B. Maschke, O. Egeland, *Dissipative Systems Analysis and Control: Theory and Applications*, 3rd Edition, Springer, 2020

but mainly on journal papers.

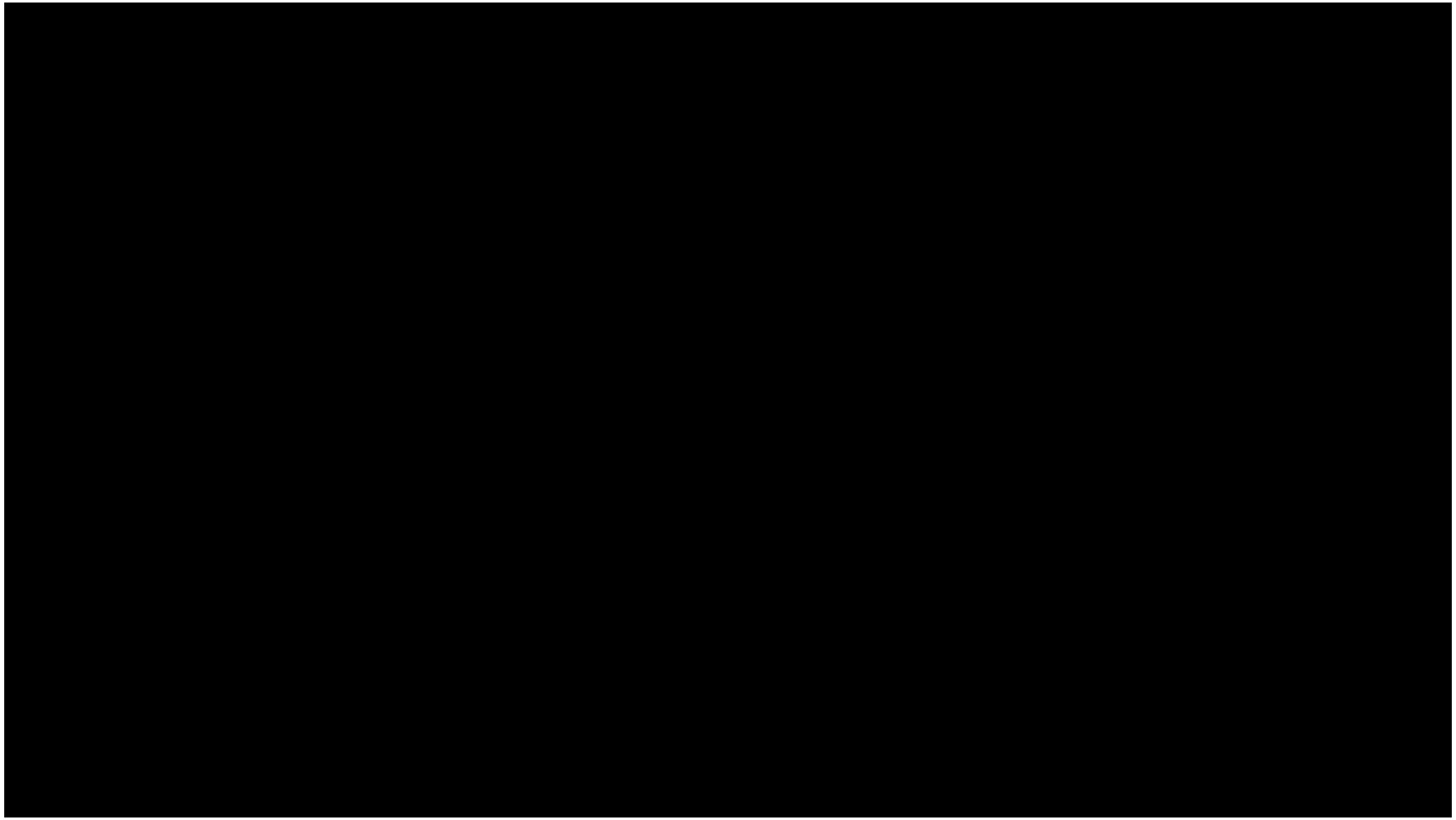
References will be provided to download them (VPN).

The pdf of the slides will be uploaded on the course webpage within encrypted .zip files.

The password is **pHRI22_6**

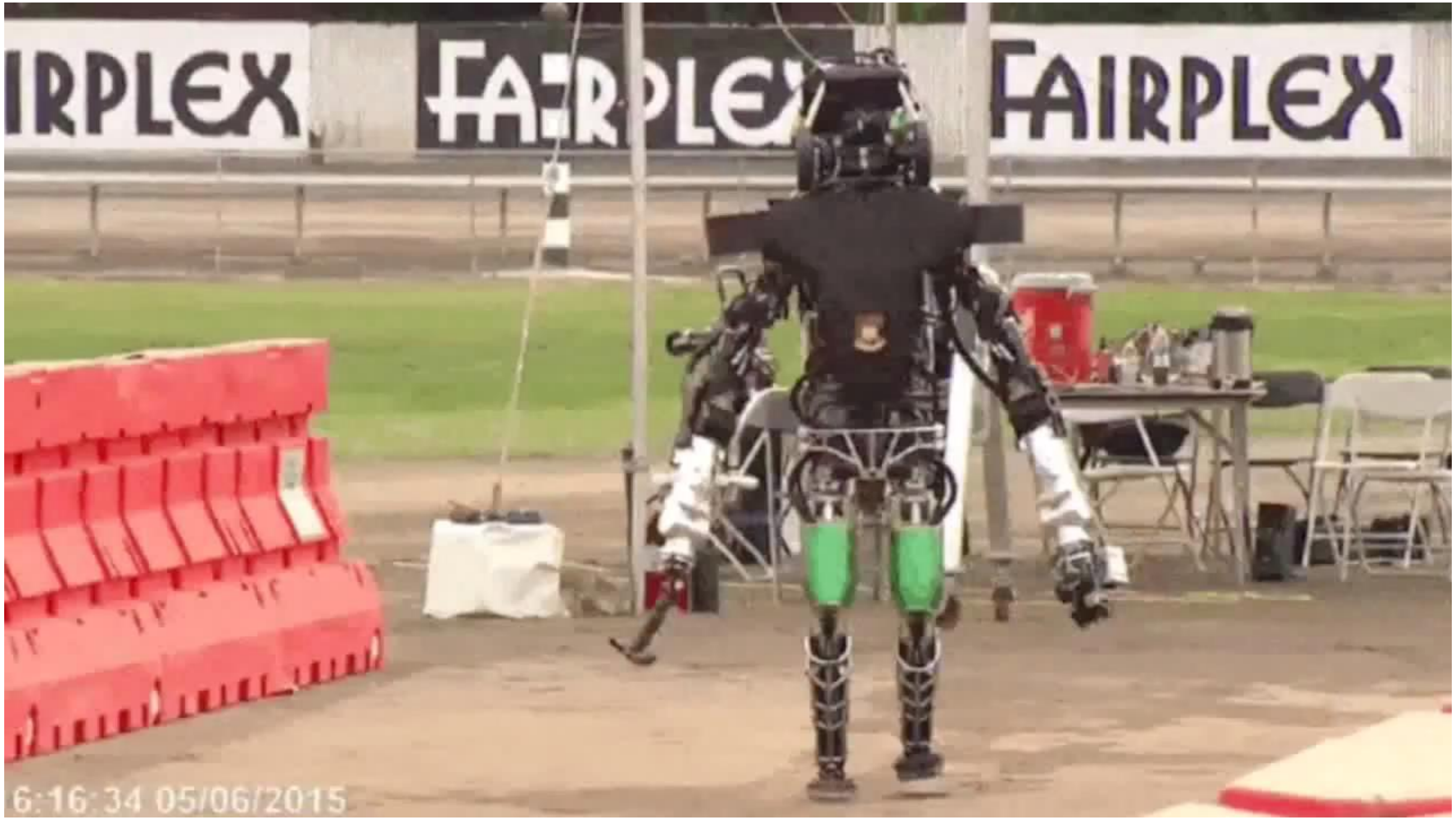
PHYSICAL INTERACTION

What we would like…



… and what we have

… and what we have



But also these…

STABILITY

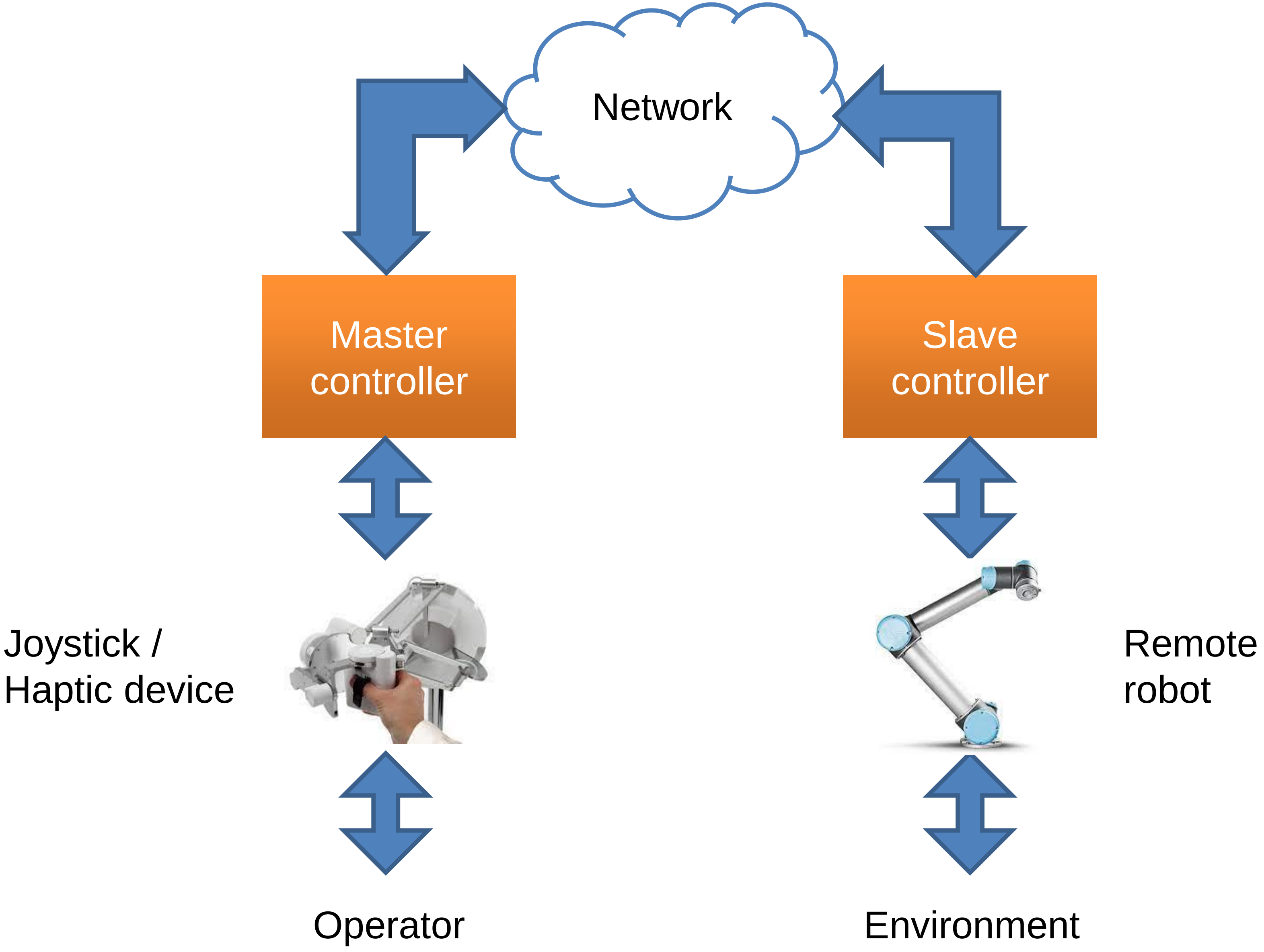
A key problem: stability

Takoma bridge

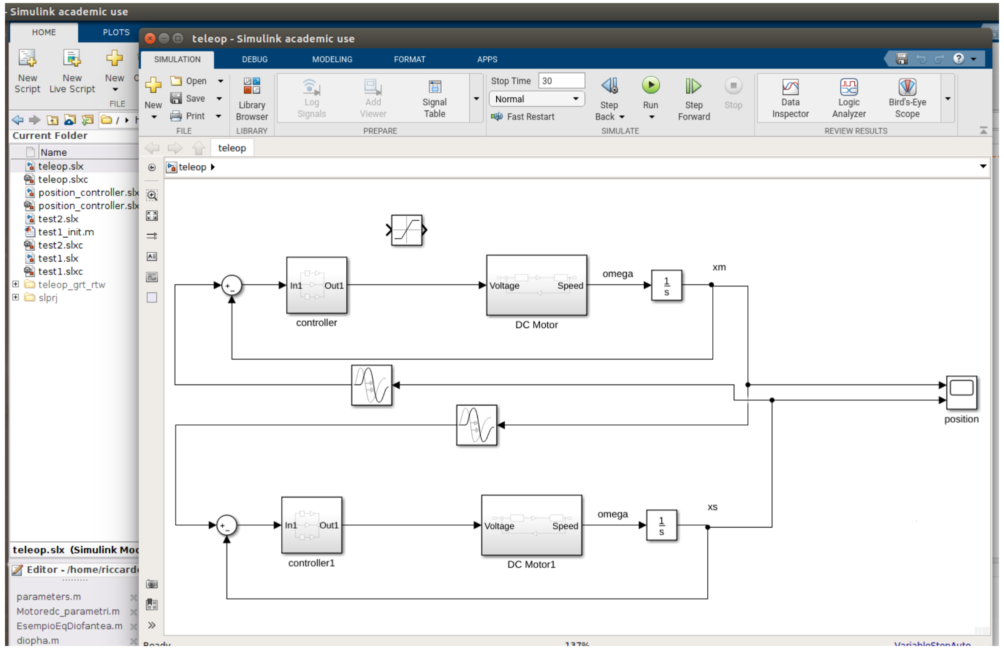
Old Mercedes Class A

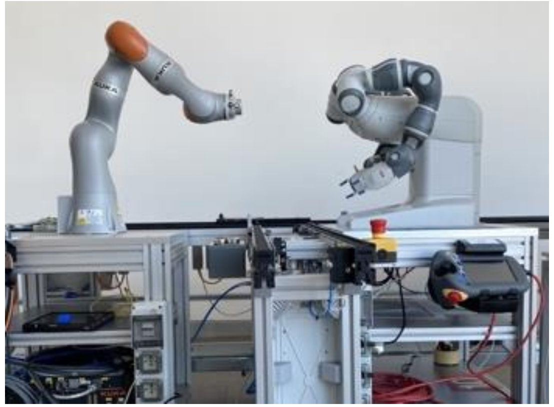
Volgograd bridge

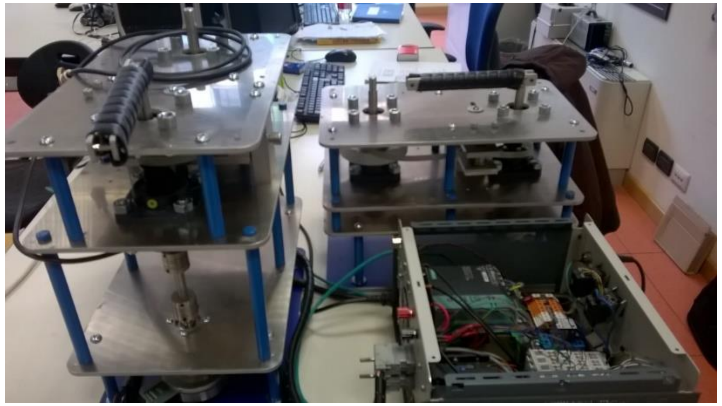
1.
We will study several **teleoperation algorithms**



2.
Implementation of the algorithms in Matlab/Simulink and/or in ROS







3.
Elastic elements in the cooperative robots
(e.g., Series Elastic Actuators)

The exam consists of *course-long* project.

Students have **to implement in Matlab/Simulink** the control architectures and the bilateral teleoperation algorithms that will be explained during the semester.

The dynamics model of the UR5 robot will be given to you. (6 degrees of freedom!)

The same robot (but with different values for the dynamic parameters) will be used both at the operator side (joystick or haptic device) and at the environment side (remotely controlled manipulator).

The exam will be **only oral** and students should prepare a brief **technical report**.

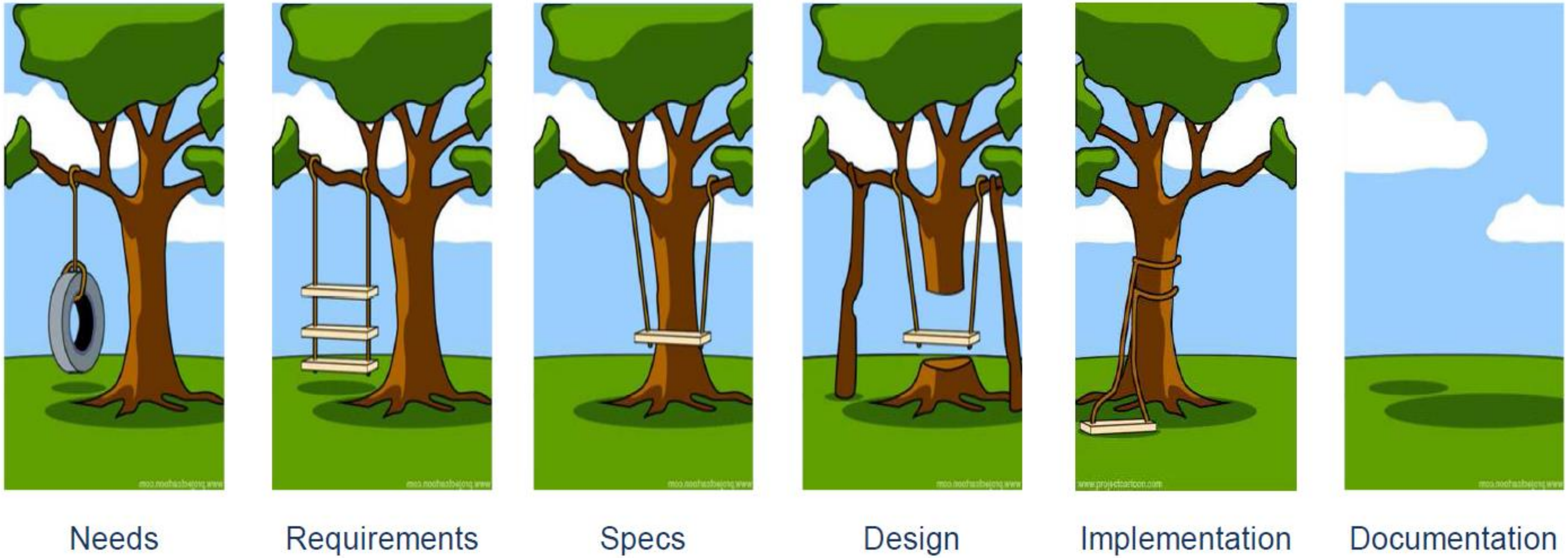
To pass the exam, students should:

- have understood the principles related to the design of the different control architectures,
- be able to use the knowledge acquired during the course to solve the assigned problem,
- be able to describe their work by explaining and motivating the design choices.

"*Tell me and I'll forget; show me and I may remember; involve me and I'll understand*"
(Confucius, 551-479 b.C.)

"*Tell me and I forget. Teach me and I remember. Involve me and I learn*"
(Benjamin Franklin, 1706-1790 a.C.)

Documentations



TELEOPERATION:
EXAMPLES AND MOTIVATIONS

Teleoperation at work

- Example of **Unilateral** teleoperation system

da Vinci system

by Intuitive Surgical

Master side

Slave side

http://www.intuitivesurgical.com/

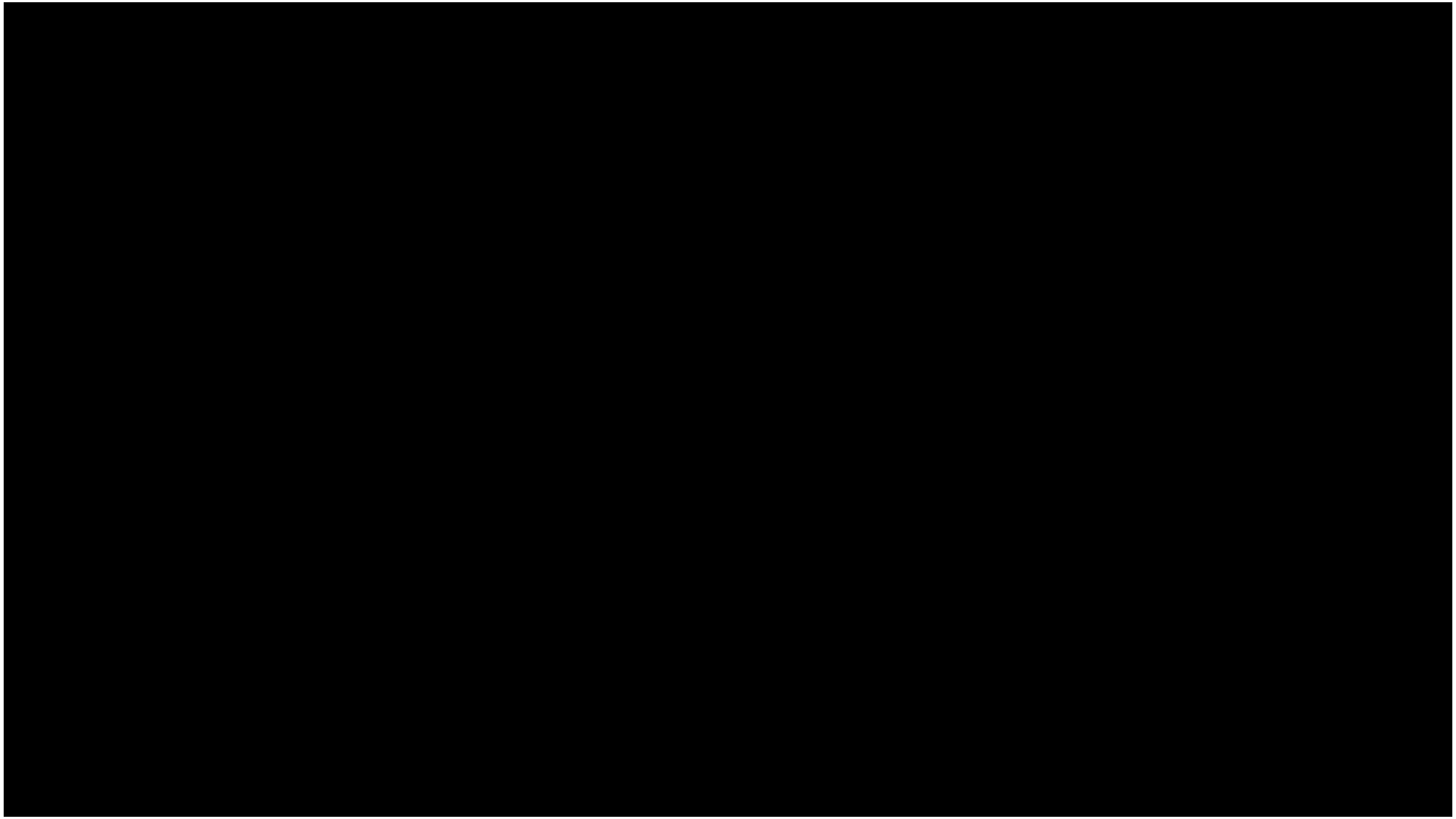
Intuitive Surgical

http://www.intuitivesurgical.com/

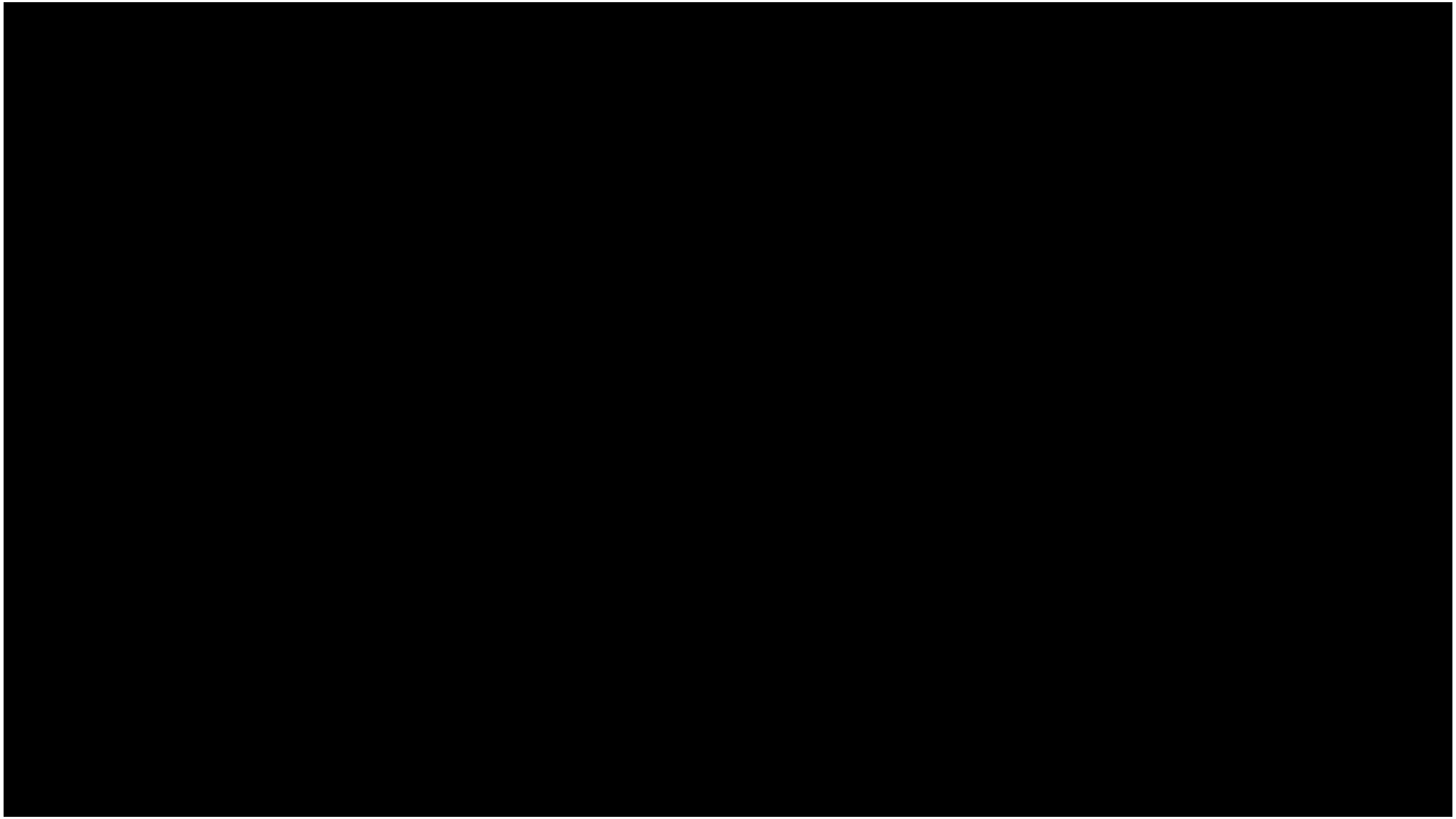
Da Vinci system

da Vinci Research Kit @ ALTAIR

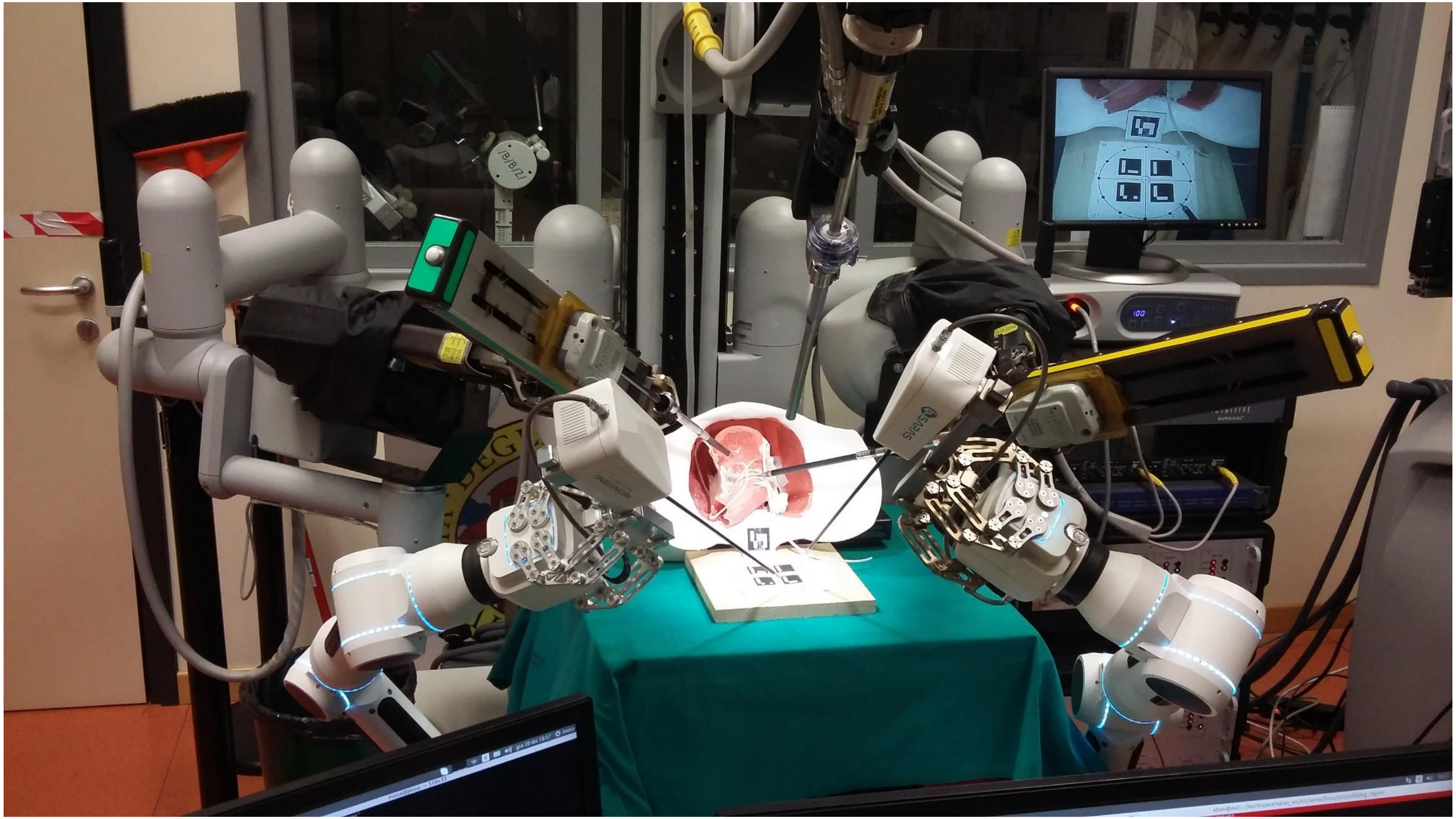
Intelligent Surgery FP7 Project I-SUR

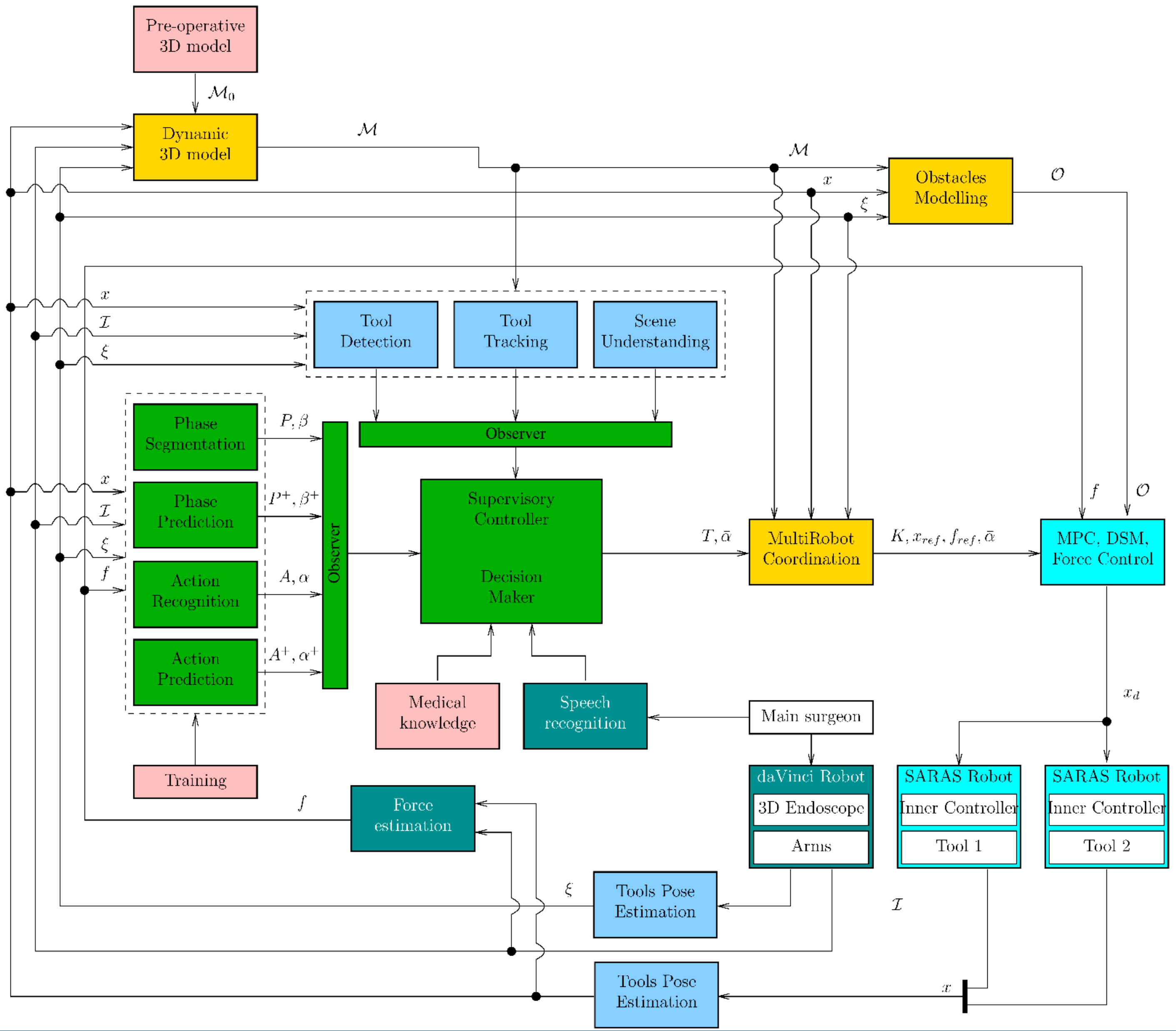


H2020 Project SARAS



H2020 Project SARAS





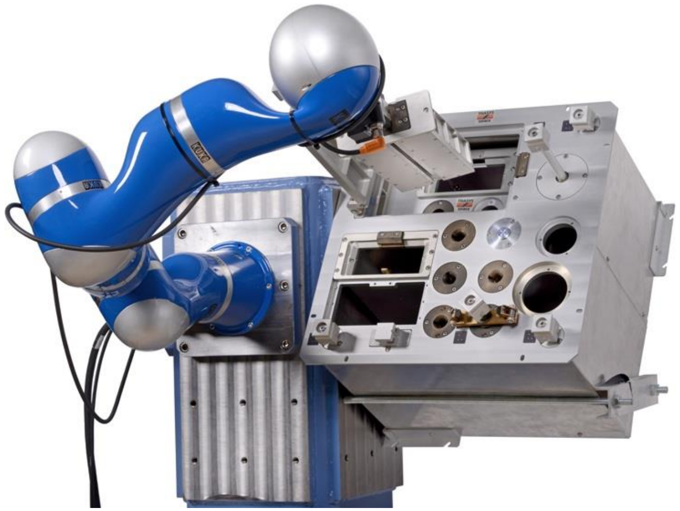
The overall architecture consists of several (state-of-the-art) modules

1. Knowledge representation
2. Human-Robot Interface
3. Perception
4. Cognitive control
5. Planning and navigation
6. Low level control

- Example of **Bilateral** teleoperation system:

Body-mounted astronaut joystick at European Space Agency (ESA)

Master side



Slave side

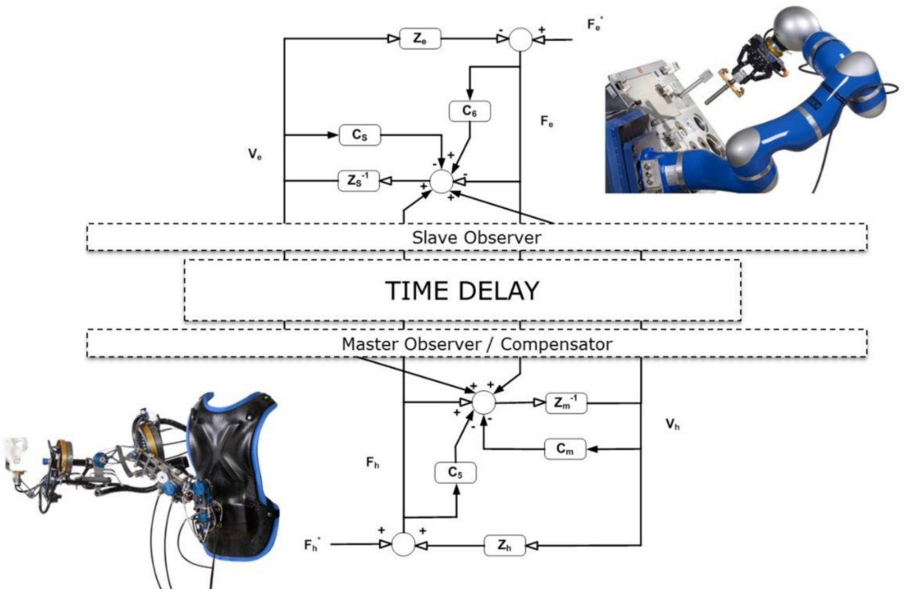
http://www.esa.int
http://www.esa.int/Our_Activities/Space_Engineering/Touchy-eely_joystick_heading_to_Space_Station

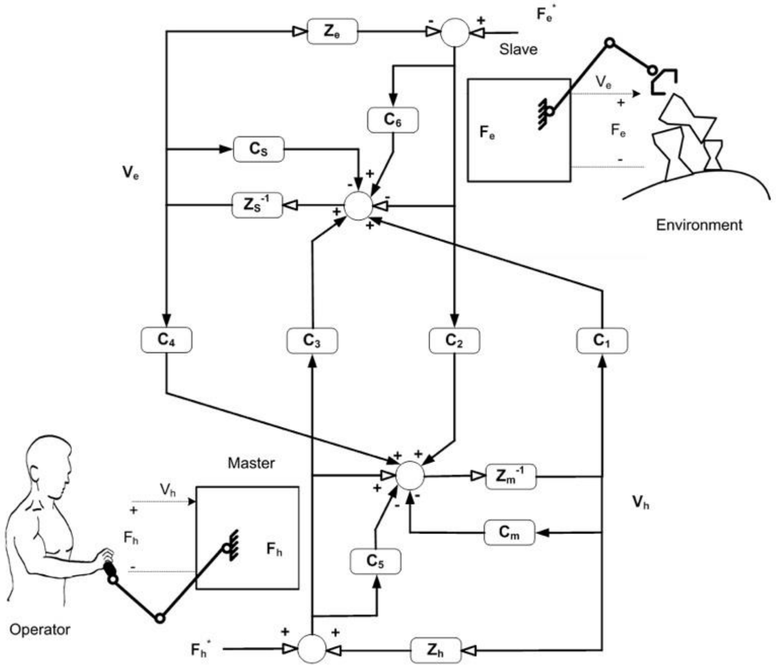
European Space Agency (ESA)

http://www.esa.int

Bilateral teleoperation

http://www.esa-telerobotics.net/index.php?page=bilateral-telemanipulation





Teleoperation at work

- Other example from robotic surgery: **Senhance™ Surgical System by** TransEnterix™

Senhance™
Surgical Robotic System

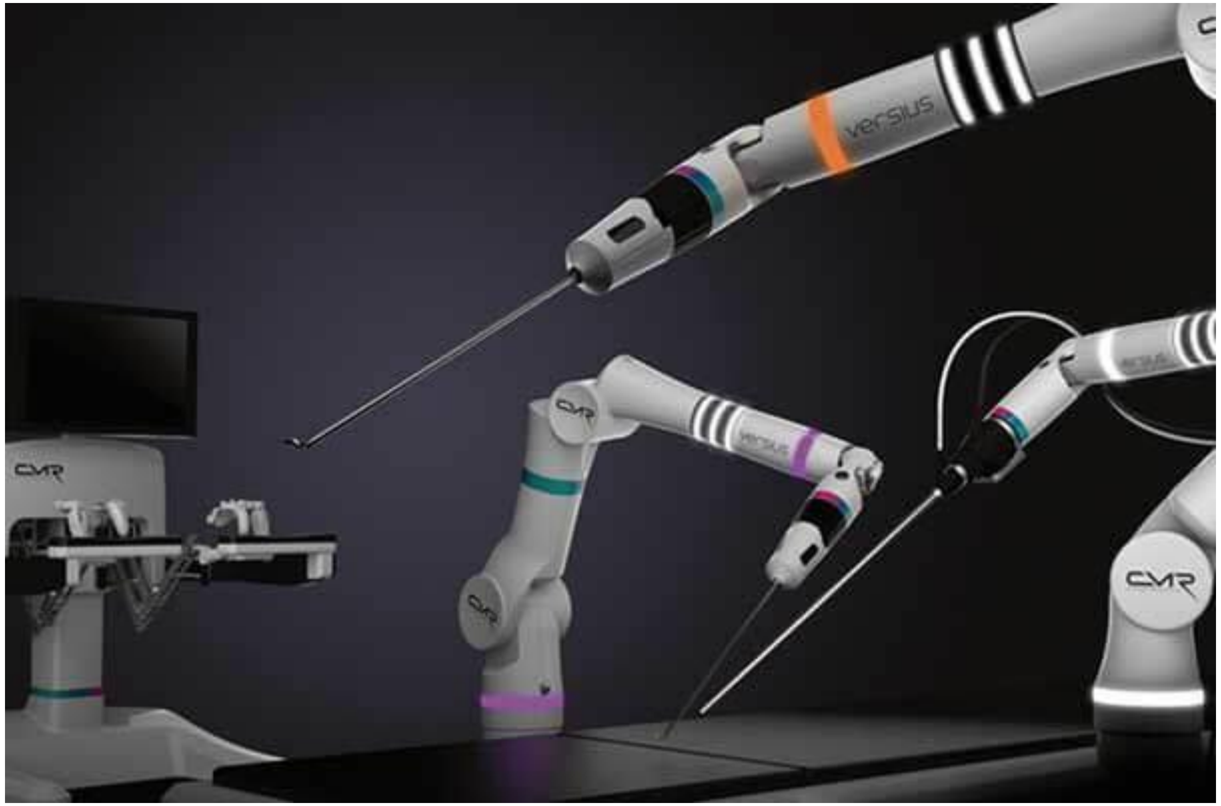
https://transenterix.com/

- Other example from robotic surgery: **SPORT Surgical System** by TITAN MEDICAL

https://titanmedicalinc.com/technology/

- Other example from robotic surgery: **Medtronic**

- Other example from robotic surgery: **Versius Surgical Robotic System** by CMR SURGICAL



https://cmrsurgical.com/versius/

- Other example from robotic surgery: Johnson & Johnson VERB SURGICAL

?

Idea behind teleoperation

Human Strengths	Robot Strengths
Strong hand-eye coordination	Good geometric accuracy
Dexterous (at human scale)	Stable and untiring
Flexible and Adaptable	Can be designed for a wide verity of scales
Can Integrate extensive and diverse information	May be sterilized
Able to use Qualitative information	Resistant to radiations and infections
Good Judgment	Can use diverse sensors in control
Easy to Instruct and Debrief	

Human Limitations	Robot Limitations
Limited dexterity outside natural scale	Poor judgment
Prone to tremor and fatigue	Limited dexterity and hand-eye coordination
Limited geometric accuracy	Limited to relatively simple procedures
Limited sterility	Expensive
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Challenges

GOAL: Guarantee a "safe" telemanipulation when interacting on one side with an *"unmodelable" operator* and on the other side with an *"unmodelable" environment*

i.e., a teleoperation system should cope with

- Unexpected behaviors
- Unmodelled environments (non-linear, unpredictable, greatly varying)
- Disturbances that may be large and ARE umpredictable

→ **Passivity (i.e., Energy awareness) is THE answer**

- Track and Control Energy flows
- No problems with stability *by contruction*
- Robust (i.e., reliable under uncertainty)
- Digital and Continuous subsystems can work together
- Handle communication delays

→ With **control by interconnection**, model uncertainty can decrease "performance" but never compromise passivity and so SAFETY