Universidad Jaume I de Castellón
Departamento de Ingeniería y Ciencia de los Computadores
Área de Arquitectura y Tecnología de Computadores

History of Telerobotics

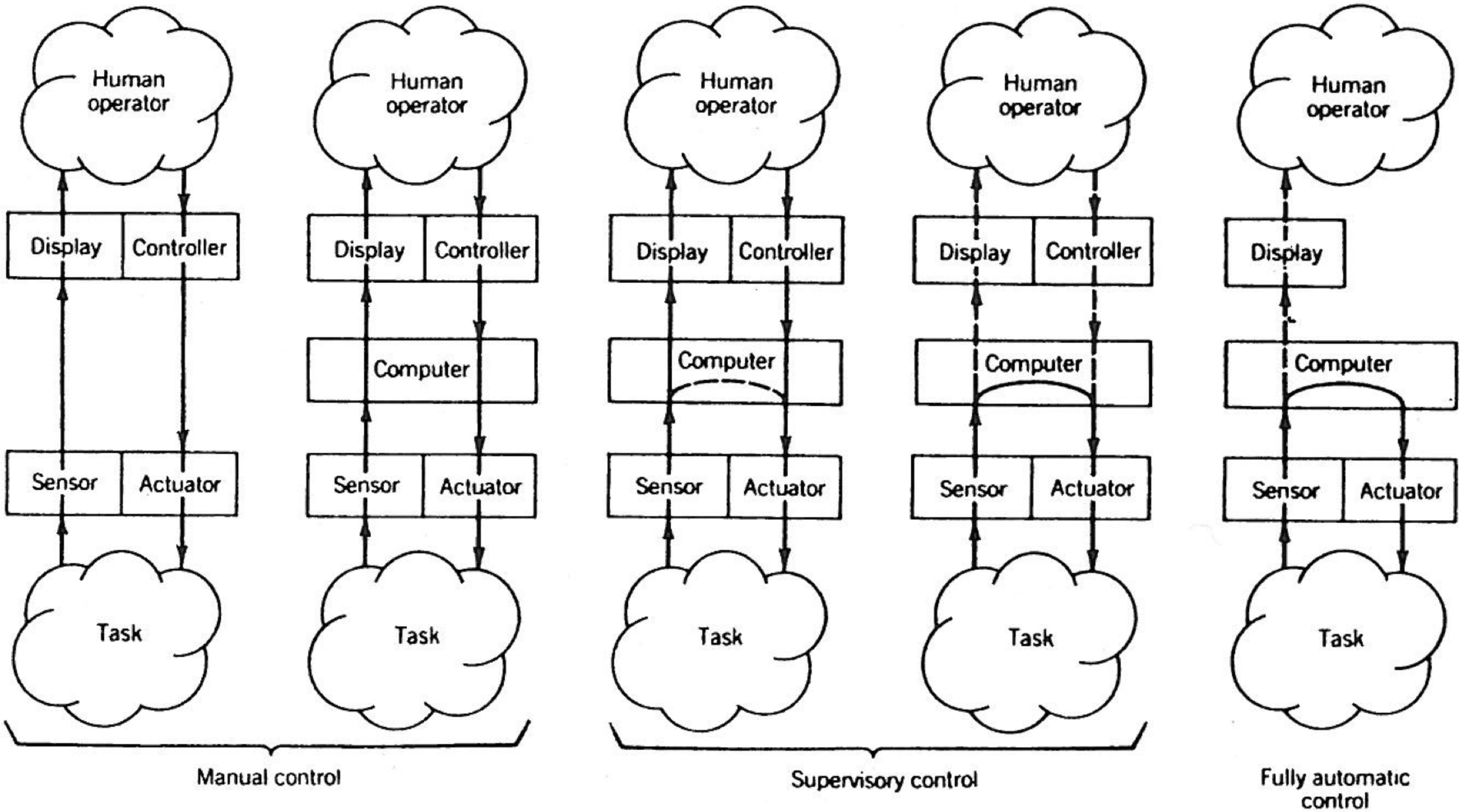
Raul Marin (rmarin@icc.uji.es)

Human supervisory control

Strictest sense: One or more human operators are <u>intermittently programming</u> and <u>continually receiving</u> information from a computer that itself closes an autonomous control loop through artificial effectors and sensors to the controlled process or task environment.

Less strict sense: One or more human operators are <u>continually programming and receiving</u> information from a computer that interconnects through artificial effectors and sensors to the controlled process or task environment.

Some Necessary Definitions



Some Necessary Definitions

Shared Control

Human may act as supervisor with respect to control of some variables and direct controller with respect to other variables.

Traded Control

Human may remain as a supervisor, or may from time to time assume direct control.

Some Necessary Definitions

Automation

Automatically controlled operation of an apparatus, a process, or a system by mechanical or electronic devices that take the place of human organs of observation, decision, and effort.

Robot

Automatic apparatus or device that performs functions ordinarily ascribed to human beings, or operates with what appears to be almost human intelligence

Some Necessary Definitions

Teleoperator

Machine that extends a person's sensing and/or manipulating capability to a location remote from that person.

Teleoperation

Direct and continuous human control of the teleoperator. It can be used in a more generic way as telerobotics.

Telerobot

Is an advanced form of teleoperator the behaviour of which a human operator supervises through a computer intermediary. The subordinate telerobot executes the task on the basis of information received from the human operator plus its own artificial sensing and intelligence.

Some Necessary Definitions

Supervisory Control

Commonly used to refer to human supervision of any semi-autonomous system (an aircraft, a chemical or power plant, etc).

Telerobotics

Supervisory Control of a Teleoperator (a machine that is remote from the operator).

Some Necessary Definitions

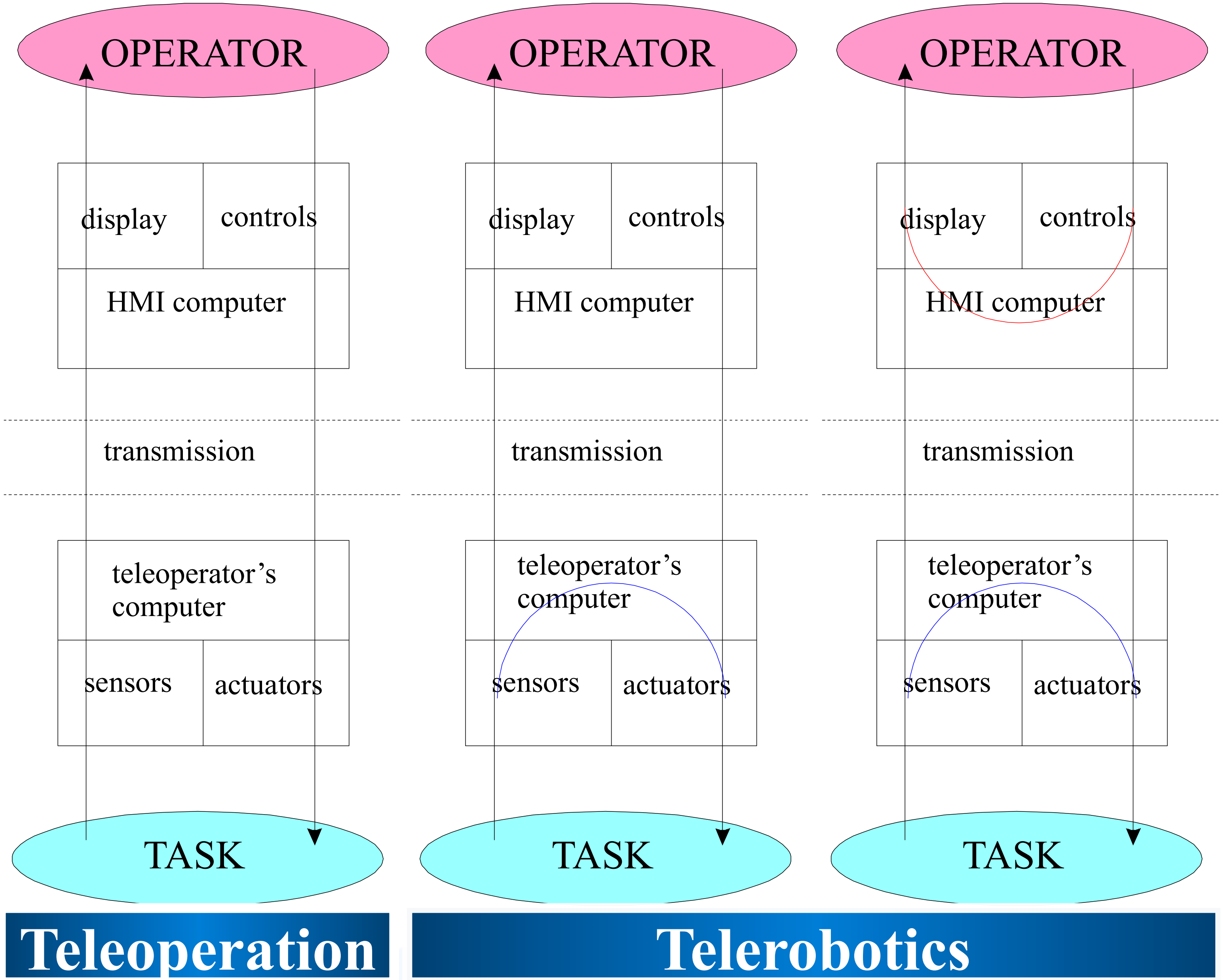
Telepresence

When the operator receives sufficient information about the teleoperator and the task environment, displayed in a sufficiently natural way, that the operator feels physically present at the remote site.

Virtual presence, virtual environment, virtual reality

Experienced by a person when sensory information generated only by and within a computer compels a feeling of being present in an environment other than the one the person is actually in.

Some Necessary Definitions



The Computer

Late 1950, the computer began to intervene in the causal loop:

1. **Electronic compensation**
2. **Stability augmentation for control of aircrafts**
3. **Electronic filtering of signal patterns in noise**
4. **Electronic generation of simple displays.**

Supervisory Control (Ferrell and Sherindan 1967)

Research on how people on earth might teleoperate vehicles on the moon through three-second RTT. It was possible to use move-and-wait technique. It was necessary to:

1. **The loop do not have to close on the user.**
2. **The user communicates goals and monitors results**
3. **Remote Subordinate Control System for implementation.**

Motivations of Supervisory Control

1. To achieve the accuracy and reliability of the machine without sacrificing the cognitive capability and adaptability of the human.
2. To make the control faster and unconstrained by the limited pace of the continuous human sensorimotor capability.
3. To make control easier by letting the operator give instructions in terms of objects to be moved and goals to be met, rather than instruments to be used and control signals to be sent.
4. To eliminate the demand for continuous human attention and reduce the operator's workload.
5. To make control possible even where there are time delays in communication between human and teleoperator.
6. To prove "fail-soft" capability when failure in the operator's direct control would prove catastrophic.
7. To save lives and reduce cost by eliminating the need for the operator to be present in the hazardous environments, and for life support required to send the operator there.

Motivations of Supervisory Control

1. To achieve the accuracy and reliability of the machine without sacrificing the cognitive capability and adaptability of the human.
2. To make the control faster and unconstrained by the limited pace of the continuous human sensorimotor capability.
3. To make control easier by letting the operator give instructions in terms of objects to be moved and goals to be met, rather than instruments to be used and control signals to be sent.
4. To eliminate the demand for continuous human attention and reduce the operator's workload.
5. To make control possible even where there are time delays in communication between human and teleoperator.
6. To prove "fail-soft" capability when failure in the operator's direct control would prove catastrophic.
7. To save lives and reduce cost by eliminating the need for the operator to be present in the hazardous environments, and for life support required to send the operator there.

Signals transmitted

Channel	Type of signals	Sample size (pixels or n. of bits)	Samples per second	Bandwidth
Visual				
	TV video (PAL/NTSC)	720x480 - 720x576	25 - 30 frames/s	165,9 Mbps
	TV Video compres. (DVD quality)	720x480 - 720x576	25 - 30 frames/s	5,2 Mbps
	Stereo video (uncompressed)	640x480	30 - 70 frames/s	147 - 344 Mbps
	Stereo video compres. (DVD quality)	640x480	30 - 70 frames/s	6,3 - 14,6 Mbps
Auditory				
	Stereo sound quality CD	16 bits x 2 channels	44,1 kHz	1,4 Mbps
	Mono sound quality telephone	12 bits x 1 channel	8,0 kHz	96 kbps
Haptics				
	Tactile	10 bits (per point)	0-10 kHz	0-100 kbps/point
	Soft contact forces	10 bits (per DoF) (6 DoF)	0,1-1,0 kHz	6-60 kbps
	Hard contact forces	10 bits (per DoF) (6 DoF)	10-100 Hz	0,6-6 kbps

Delays

Thomas B. Sherindan. Space Teleoperation through Time Delay: Review and Prognosis. IEEE Transactions on Robotics and Automation Vol. 9. Num. 5. October 1993

Space Teleoperation Through Time Delay: Review and Prognosis

Thomas B. Sheridan, *Fellow, IEEE*

Abstract—**The paper reviews a 30-year history of research on dealing with the effects of time delay in the control loop on human teleoperation in space. Experiments on the effects of delay on human performance are discussed, along with demonstrations of predictive displays to help the human overcome the delay. Supervisory control is shown to offer a variety of options, from switching to local impedance control upon contact with the environment to higher-level local automation. Wave transformation techniques to ameliorate the effects of delay are also described. Space teleoperations have tended to deal with the problem of time delay by avoiding it and not attempting to teleoperate from the ground. The paper opines that our space effort might have gotten**

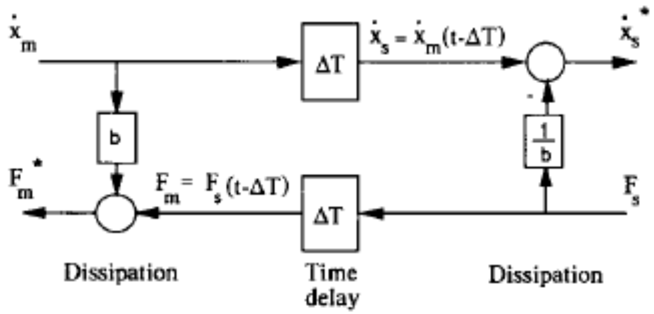


Fig. 1. Damping to stabilize a teleoperator communications process [1].

Delays

Thomas B. Sherindan. Space Teleoperation through Time Delay: Review and Prognosis. IEEE Transactions on Robotics and Automation Vol. 9. Num. 5. October 1993

Teleoperation Scenario	Delay
Vehicle in low-earth orbit Vehicle on or near the moon	RTT >= 0.4 s RTT 3 s
Earth-orbiting space shuttle with multiple up-down links (earth to satellite or the reverse)	RTT 6 s
Accoustic deep ocean teleoperation at 1700m	RTT 2s (1700 m/s)
Voyager outer solar system	RTT 3 h

For delays Z 0.5 and operator movements slow (z 1Hz) a predictor display can be very useful

Fire Tong/Handle

Animal Prods

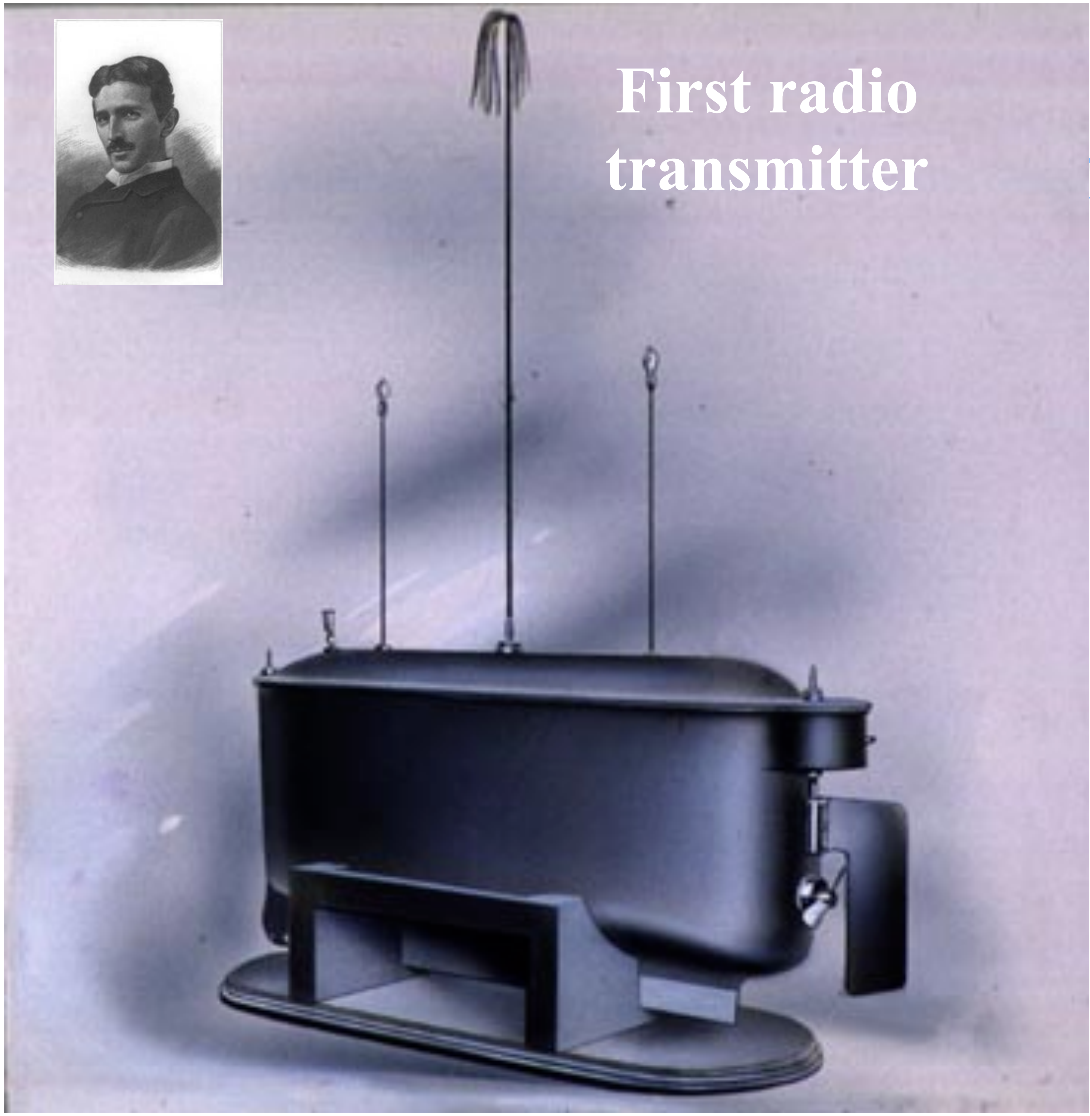
- Tool – to improve the work task, to make something possible
- Teleoperation – to avoid hostile environment, usually neither the quality nor the efficiency of the work is improved

Animal Prods

Bell Ring

Previous Next

Nikola Tesla (1898)

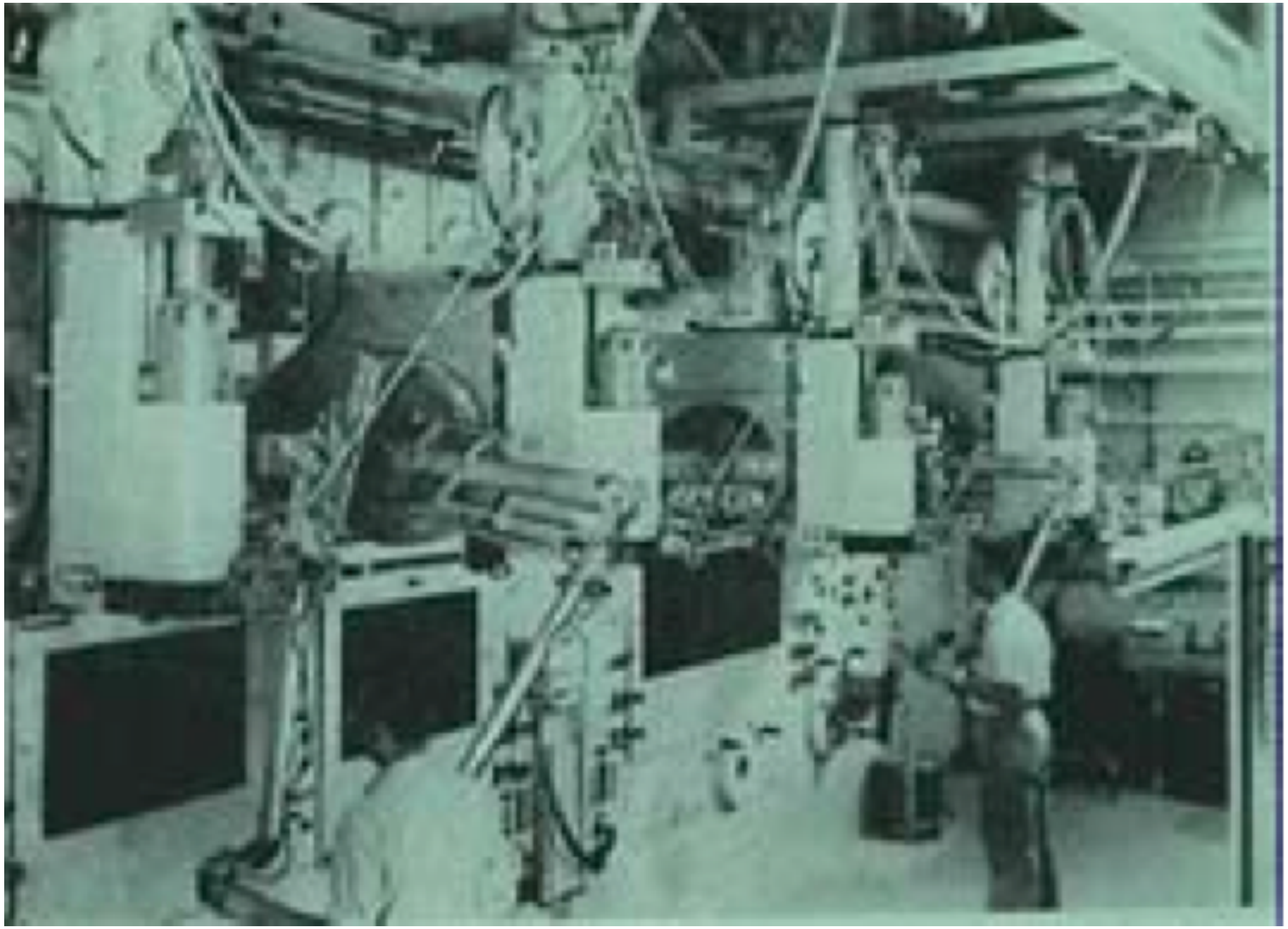


Goertz at Argonne National Laboratory (40s)

- The first *modern* master - slave teleoperators were mechanical pantographs.
- These manipulators were developed by the group of R. Goertz in the late 1940s at the Argonne National Laboratory where Enrico Fermi developed the first nuclear reactor

Goertz at Argonne National Laboratory (54)

- The mechanical manipulators were soon replaced by electro mechanical servos
- In 1954 Goertz's team developed the first electro mechanical manipulator with feedback servo control.
- After this the teleoperation of manipulators and vehicles spread out rapidly to new branches where advantages of teleoperation techniques could be utilized.

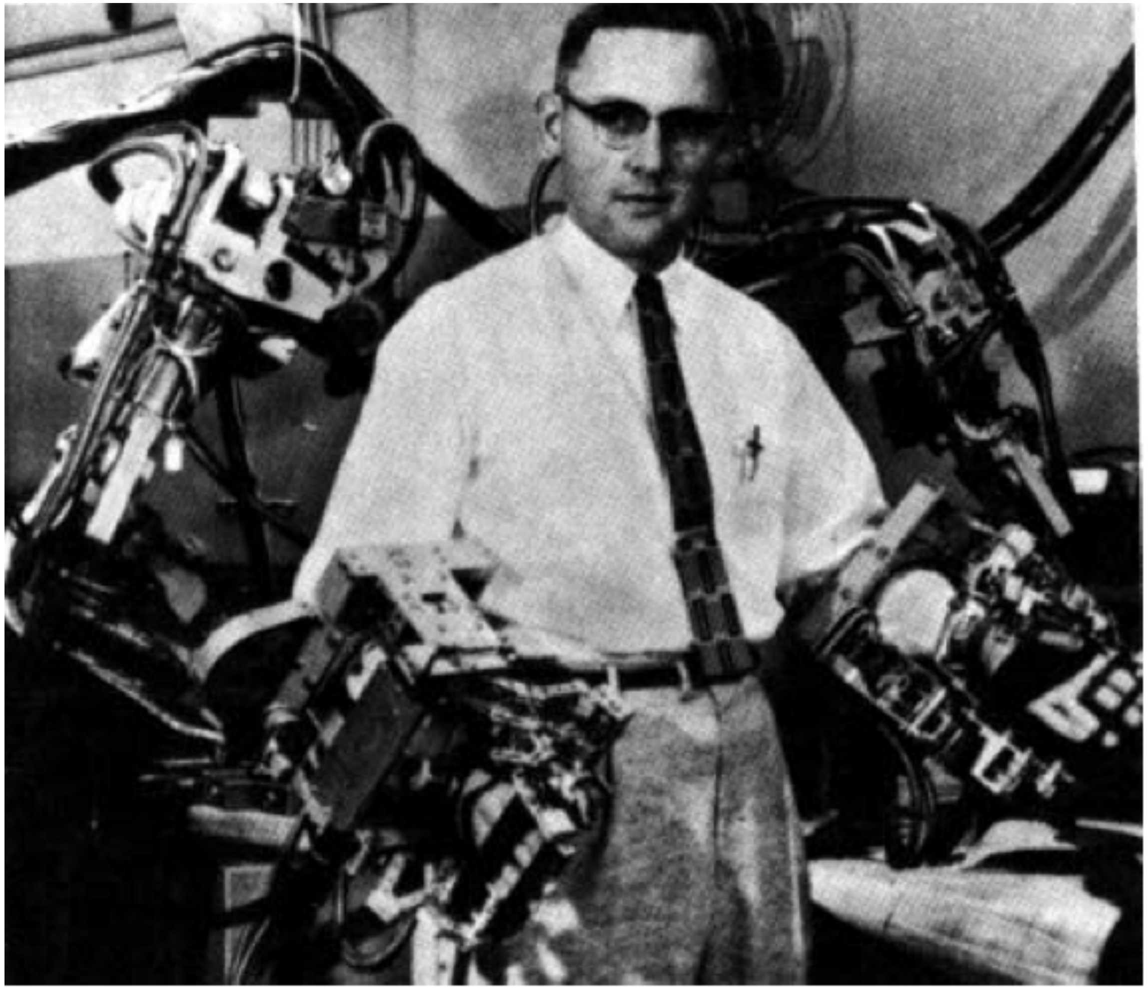


Flashmatic 1956. First remotely controlled TV

Flashmatic, First remotely controlled TV (1956)

Mosher's Handyman (60s)

- Two electrohydraylic arms each with ten DOF (two DOF for each of five fingers). Telepresence, Force-Reflection, display.

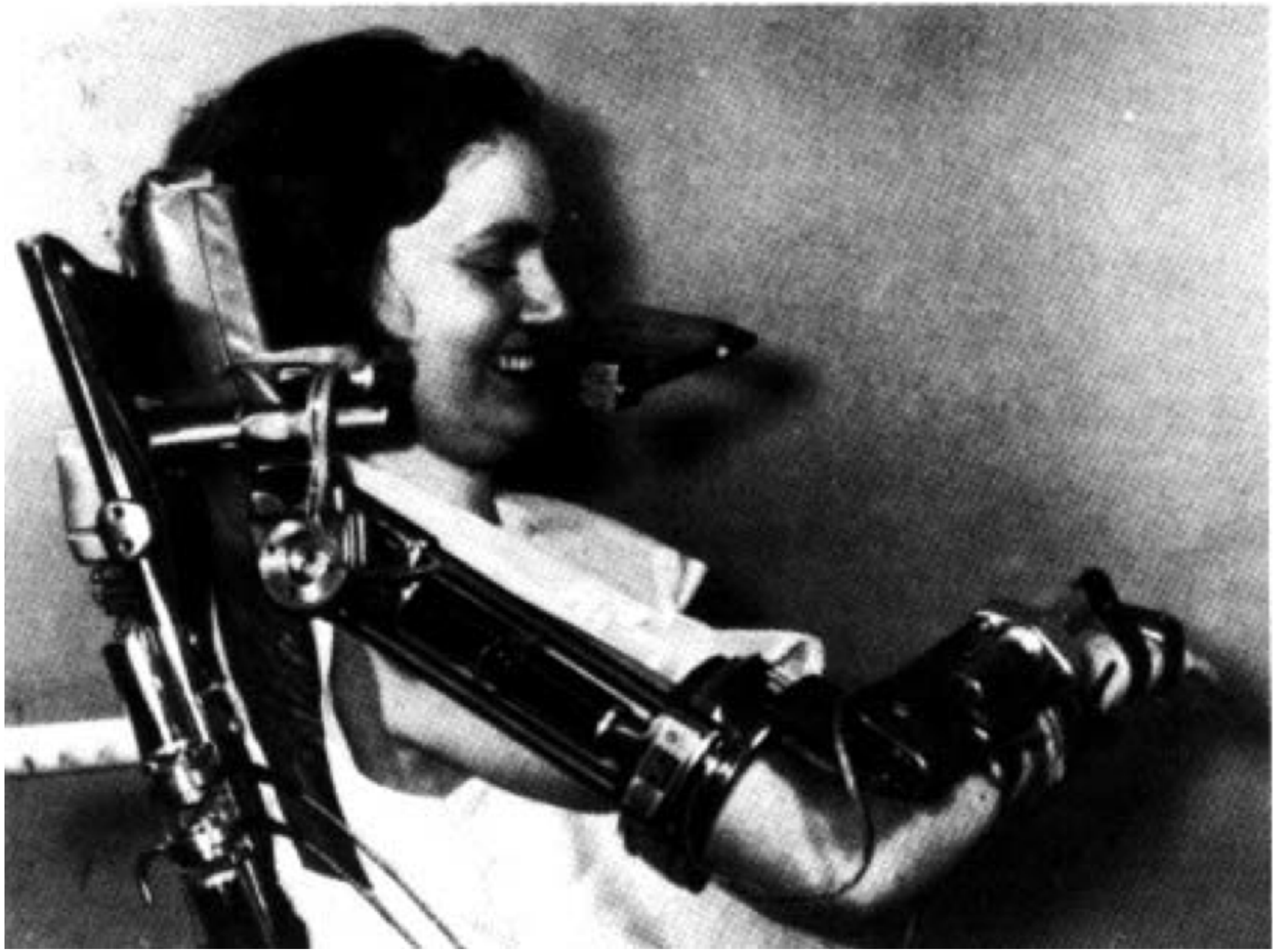


Aaron Kobrinskii (1960)

- Lower-arm prosthesis driven by minute myoelectric signals picked up from the muscles in the stump or upper arm

Teleoperators in wheelchairs (1960s)

- Teleoperators attached to the wheelchairs of quadraplegics which could be commanded by the tongue or other remaining motor signals

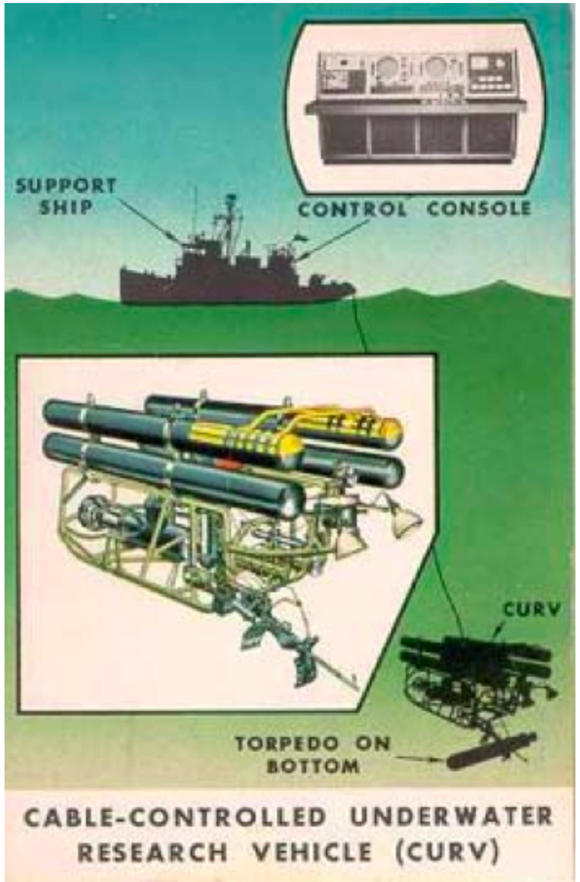


CURV vehicle(1966s)

- The US Navy's CURV vehicle was used successfully to retrieve from the deep ocean bottom a nuclear bomb that had been dropped accidentally from an airplane off Palomares, Spain.

CURV vehicle(1966s)

- The US Navy's CURV vehicle was used successfully to retrieve from the deep ocean bottom a nuclear bomb that had been dropped accidentally from an airplane off Palomares, Spain.

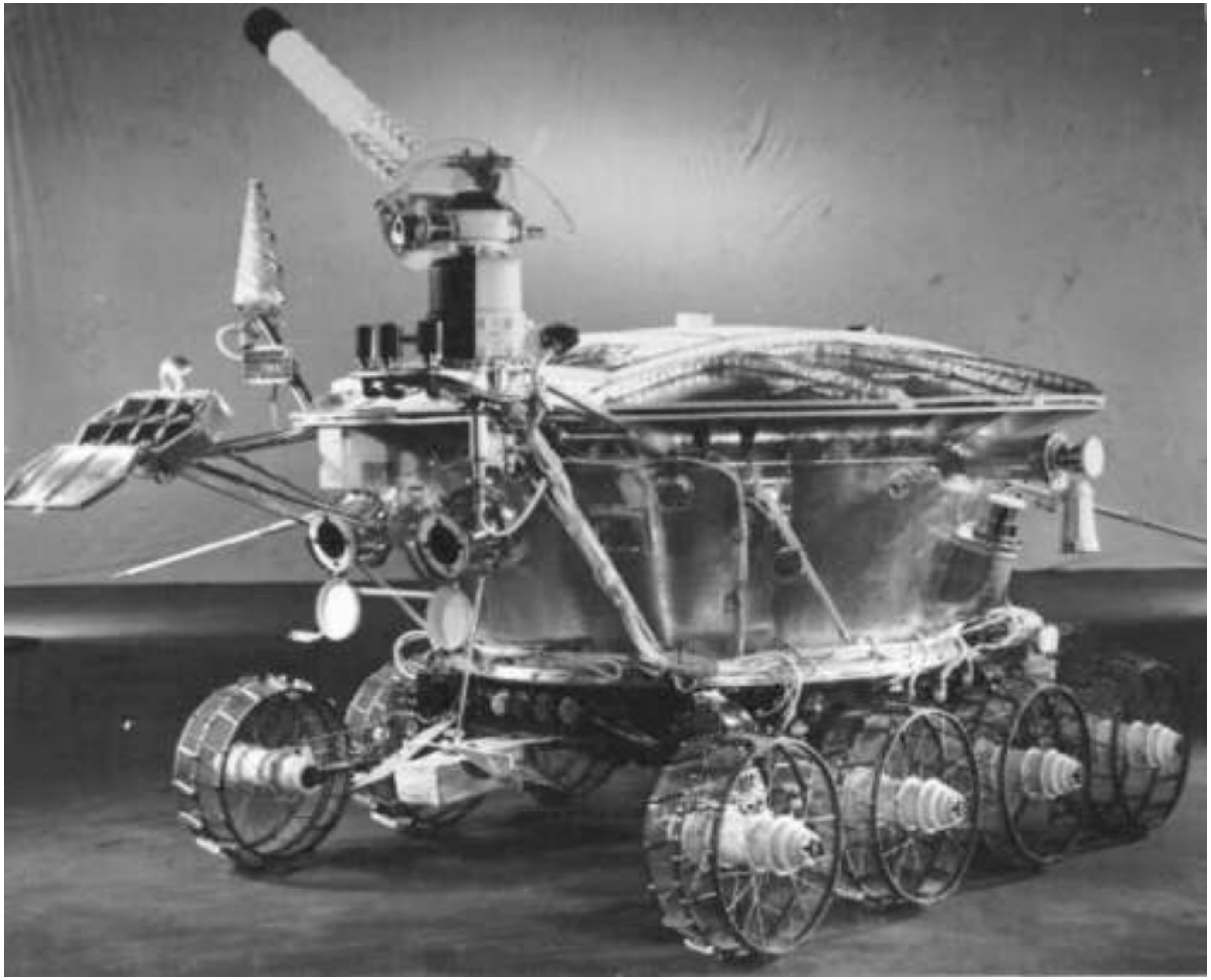


CURV vehicle(1966s)

LUNAKHOD (1970)

In 1965 first experiments in laboratory were made to investigate the instability problems in teleoperation with time delays.

LUNAKHOD (1970)

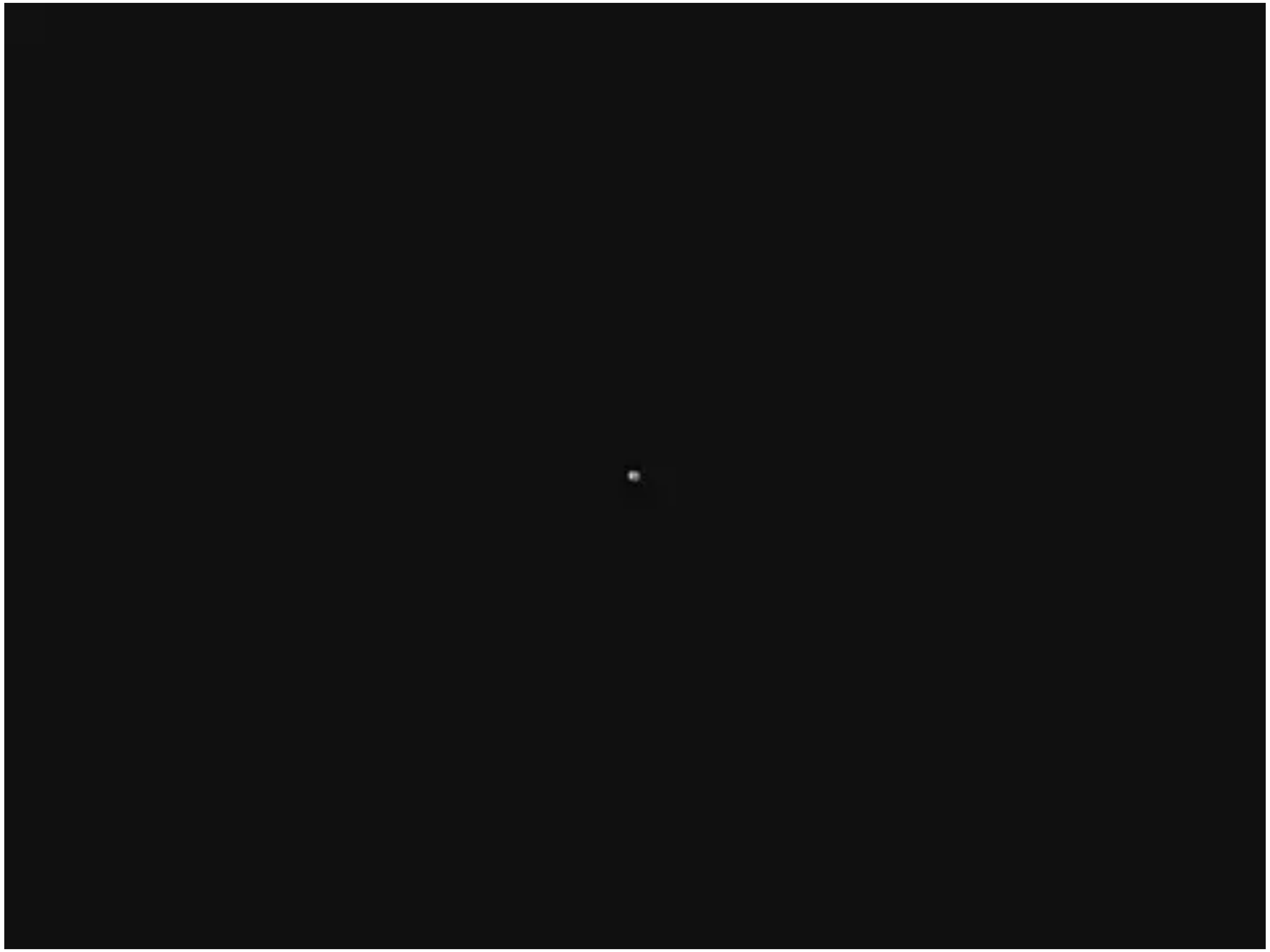


ROV (1980)

Extensive use of ROVs (Remotely Operated Vehicles) in offshore operations for oil/gas industry

ROV (1980)

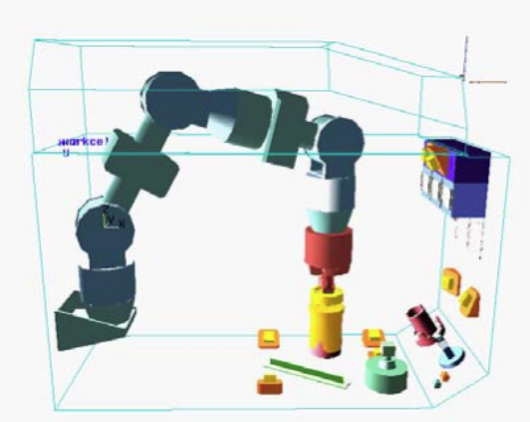
Extensive use of ROVs (Remotely Operated Vehicles) in offshore operations for oil/gas industry



History of Teleoperators

Some recent important tele-robotics examples:

- **April '93:** the space robot ROTEX was flown on space-shuttle COLUMBIA (STS 55). A multisensory robot on board the spacecraft successfully worked in several modes teleoperated by astronauts, as well as in different telerobotic ground control modes.



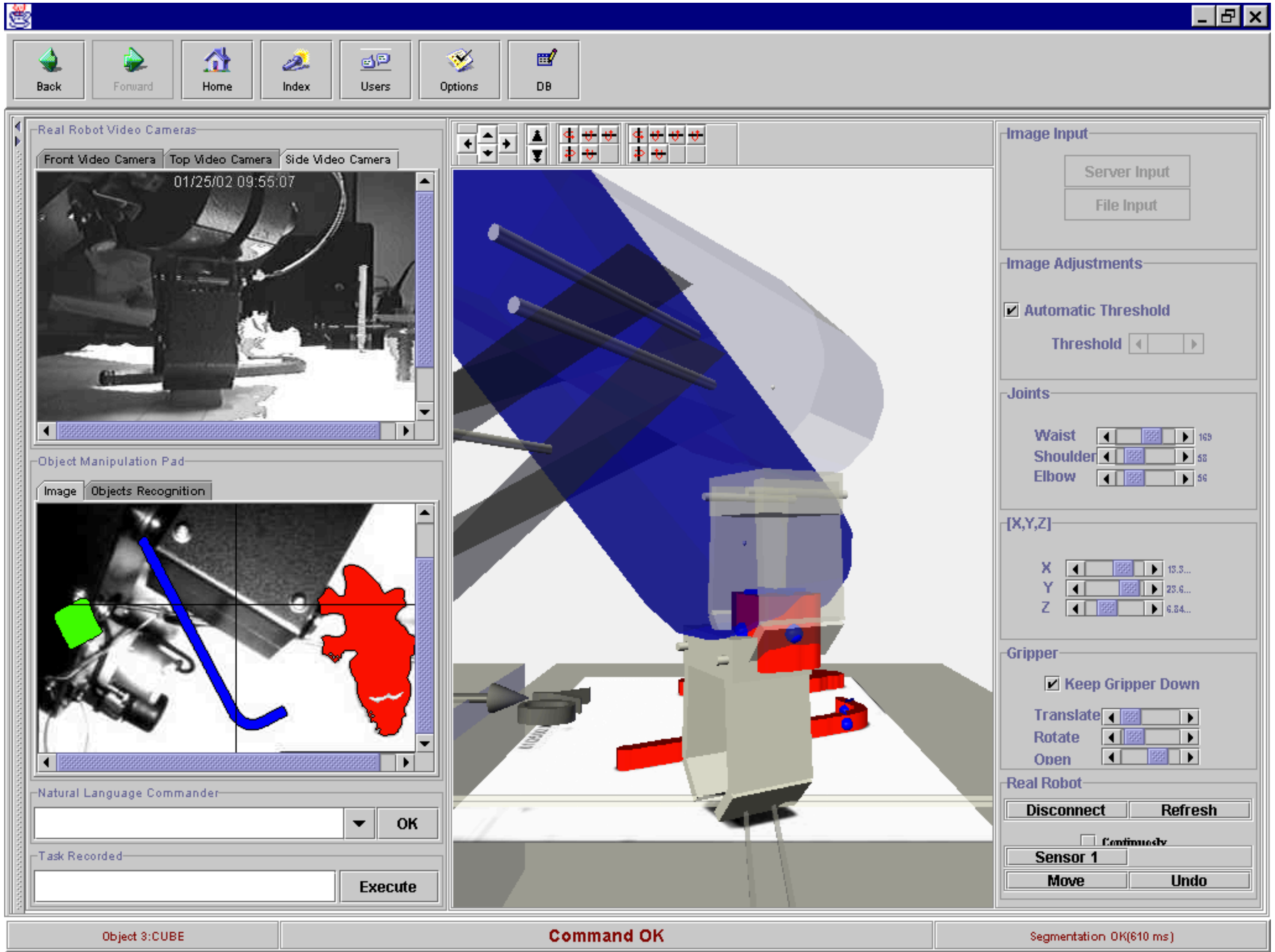
- **July '97:** the rover Sojourner landed on Mars in the Ares Vallis. From landing until the final data transmission on September 27, 1997, Mars Pathfinder returned 2.3 billion bits of information (more than 20,000 images, more than 15 chemical analyses, and extensive data on winds and other weather factors).

- **Sept. '98:** first robotic cardio-surgical operation (Prof. Boyd).

- **June '01:** the first trans-oceanic telesurgery operation (New York, USA – Strasbourg, F) (Prof. Marescaux)

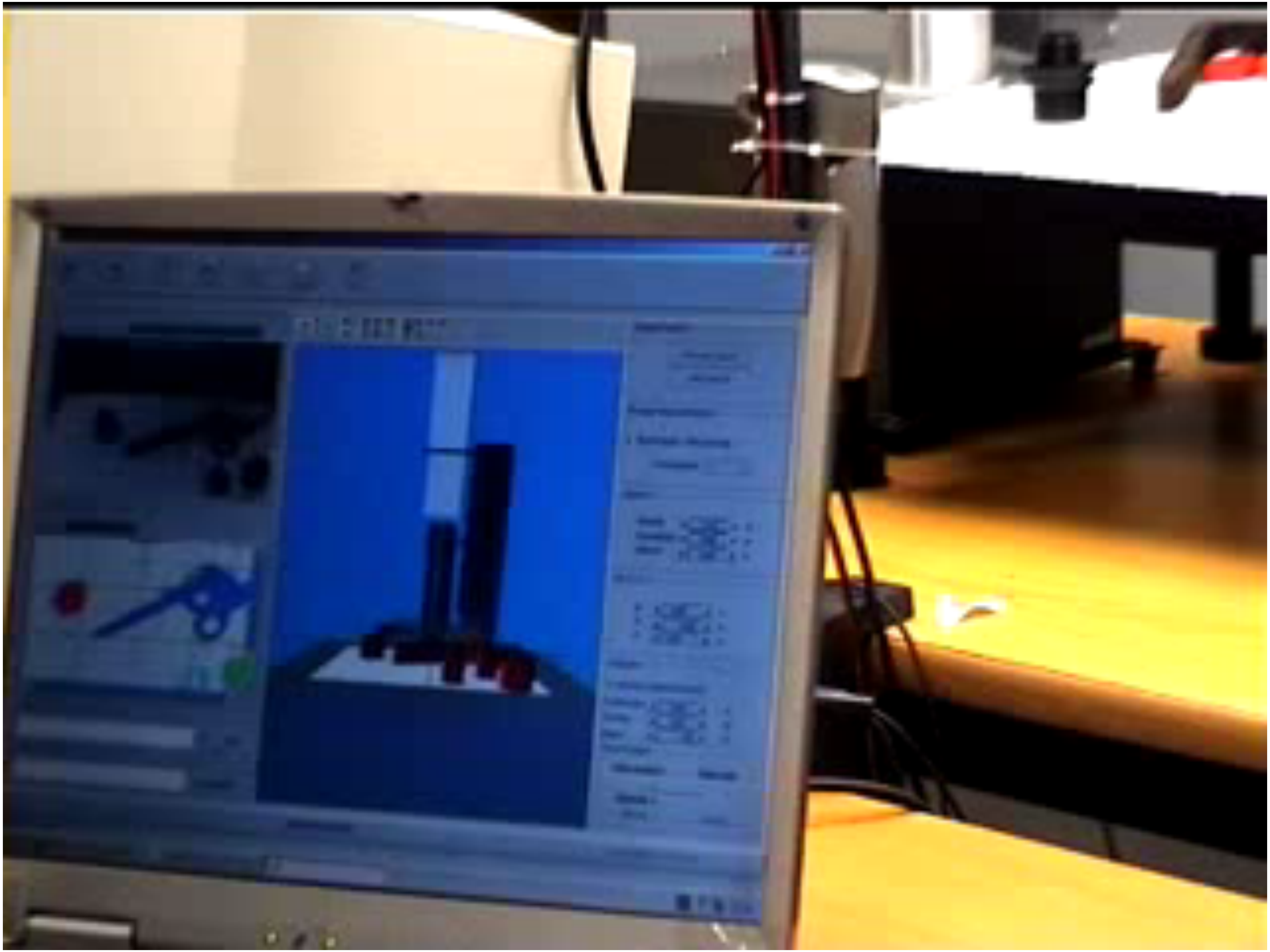
Delays

Raúl Marín Prades, Pedro José Sanz Valero, Angel Pascual del Pobil Ferre. AUTONOMOUS ROBOTS. The UJI Online Robot: An Education and Training Experience. Num. 3 (15). pp. 283-297. 2003 Internacional (científic). AUTONOMOUS ROBOTS.

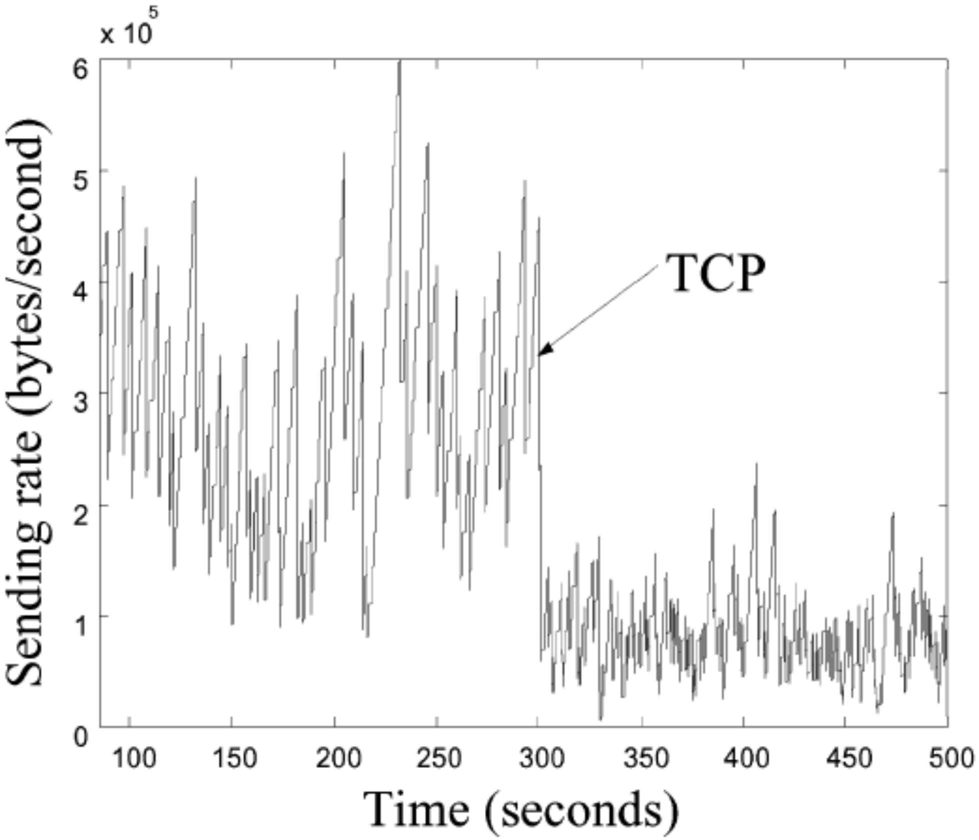


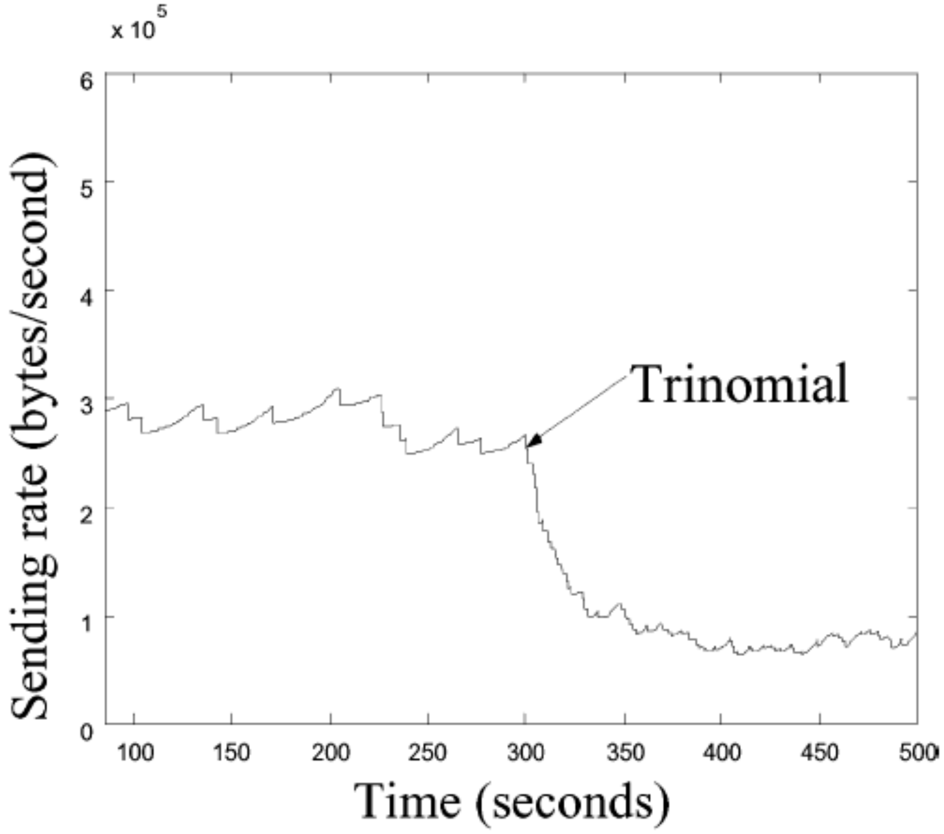
VIDEO

Previous Next



Teleoperation over Internet





Thank you