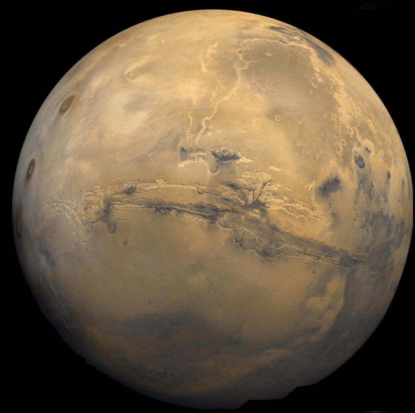
3rd Summer European University

Montpellier, 5-12. September 2007

Surgical Robots in Space

Long Distance Telesurgery



Tamas HAIDEGGER

Budapest University of Technology and Economics
haidegger@gmail.com

Tamás Haidegger: Surgical Robots in Space

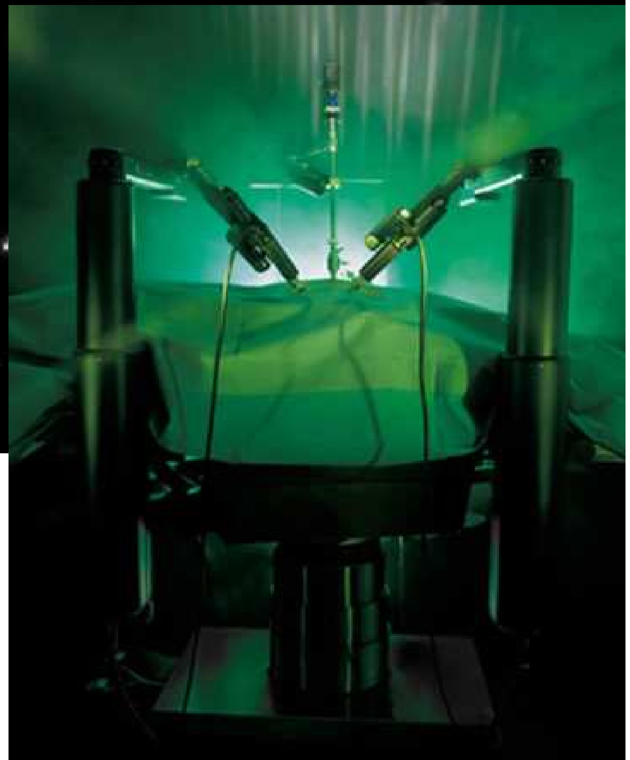
Design by Tbabe

Complete telesurgical systems

Zeus and da Vinci

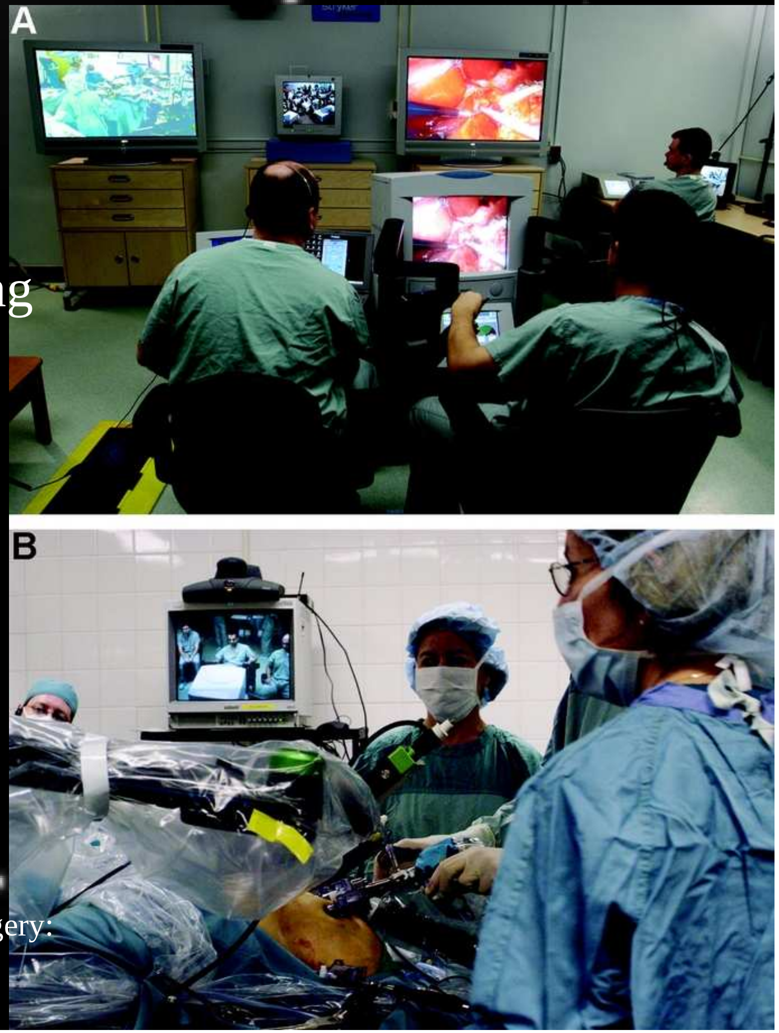
- Development by 1991/1992
- Clinical use since 1998/1999
- FDA approval: 2001

- 30% of prostatectomies performed robotically in the USA
- 1000 da Vincis in use
- Da Vinci S in 2003



Long distance telesurgery
The Lindbergh operation

- 7th September 2001
- Hour-long gallbladder removal
- New York - Strasbourg
- Master setup in an office building
- Average latency: 150 ms



*J. Marescaux et al.: Transcontinental Robot-Assisted Remote Telesurgery: Feasibility and Potential Applications; Annals of Surgery, Vol. 235, No. 4., p. 487-492., 2002

Extreme telemedicine

Space medicine for long duration manned missions

- complete health monitoring
- miniaturized integrated biosensors
- on-line clinical information system
- strategic health care research planner
  (for data analysis and support)
- medical knowledge base
  (for identifying the risks and hazards)
- astronauts should receive comprehensive
  medical training
- a skilled flight surgeon should be in crew

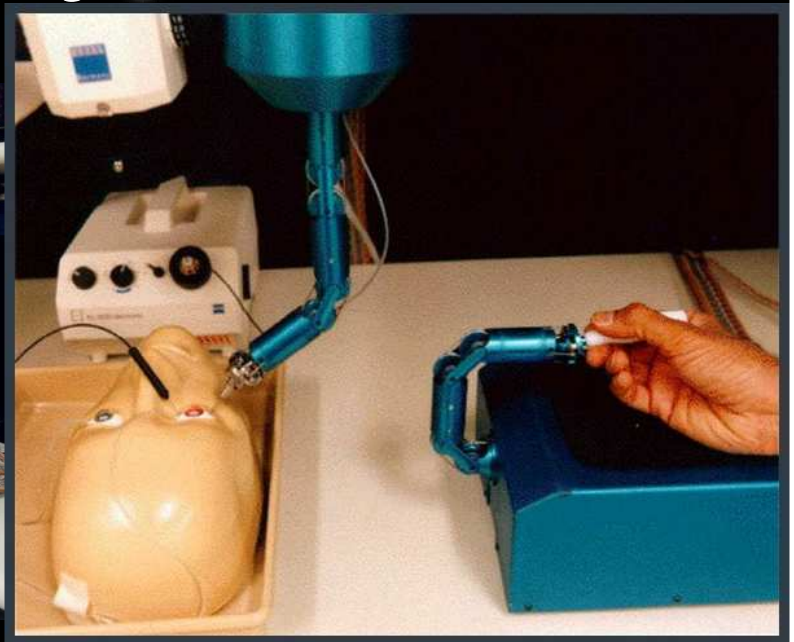
- terrestrial health support centre
- complete surgical simulator on Earth
- multimodal physiologic model of astronauts
(for reference on health status)

*NASA Space Flight Human System Standard, Volume 1: Crew Health; Space Flight Health Requirements Document, NASA-STD-3001, 2007

Surgical robots for space I.

Robot Assisted MicroSurgery (RAMS)

- NASA Jet Propulsion Laboratory, 1997
- Two 6 DOF arms for 40 ccm workspace
- 10 micron accuracy
- 1:100 scale down, tremor filtering

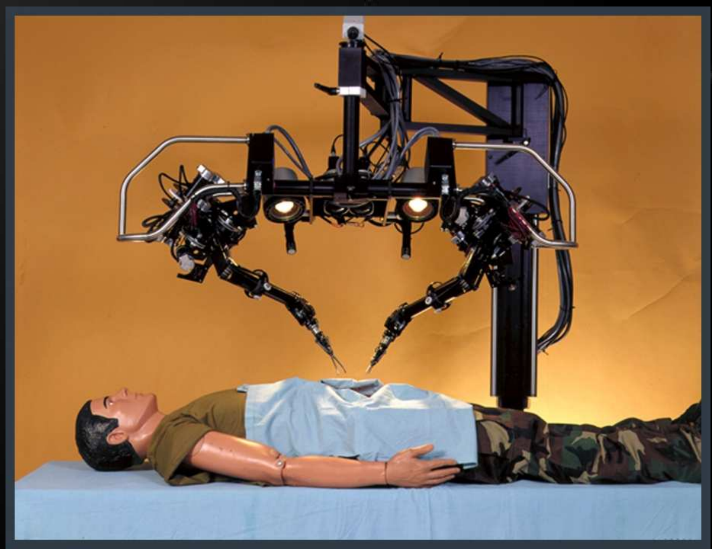


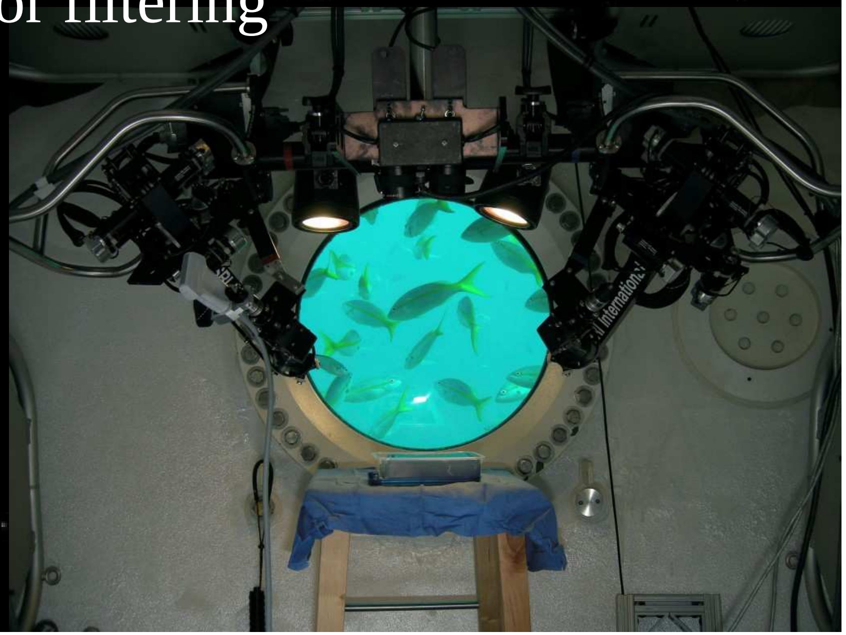
*H. Das, T. Ohm et al.: Robot Assisted MicroSurgery Development at JPL; Technical Report, 1998

Surgical robots for space II.

M7 Robot

- SRI International, 1998
- Light weight – 15 kg
- 7 DOF arms
- 1:10 scale down, tremor filtering





Surgical robots for space III
Raven

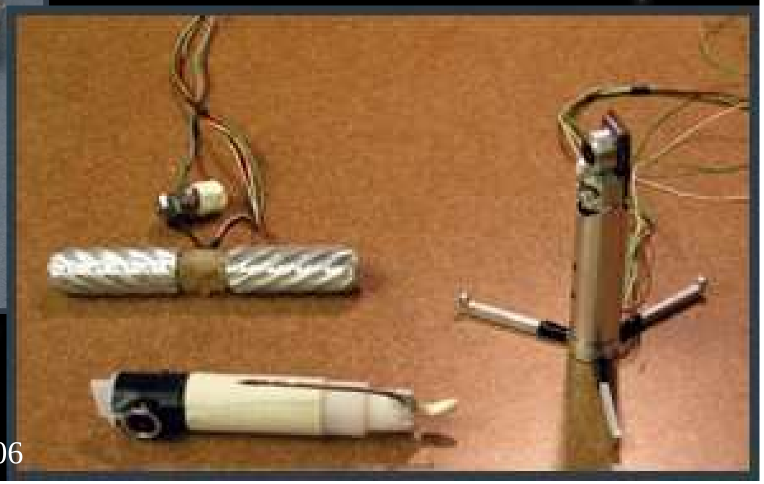
- Washington University, 2006
- 22 kg overall mass
- Capable of haptic feedback

*J. Rosen, B. Hannaford: Doc at a distance; IEEE Spectrum, Vol. 8., No. 10., p. 34-39., 2006

Surgical robots for space IV.

Mobile in-vivo robot

- University of Nebraska, 2004
- Wheeled design
- Small structure
- For biopsy and minor interventions



*M. E. Rentschler et al.: Mobile In Vivo Biopsy Robot; Proc. of the 2006 IEEE Intl. Conference on Robotics and Automation, Orlando, Florida, 2006

Teleoperation experiments

NASA Extreme Environment Mission Operation - NEEMO

7th NEEMO (October, 2004)

- Reference procedures with a Zeus
- Telesurgery from 2500 km
- 100 ms – 2 s delay
- Feasibility test for telementoring

9th NEEMO (April, 2006)

- Simulated procedures with M7
- Test of wheeled in-vivo robots
- Satellite comm., up to 3 s delay
- Telemedicine tests

12th NEEMO (May, 2007)

- Telesurgery with Raven and M7 robots
- Suturing test in zero gravity simulation
- Max. 1 s communication lag time
- Automated robotic operations

*R. Thirsk, D. Williams, M. Anvari: NEEMO 7 undersea mission; Acta Astronautica, Vol. 60., 2007

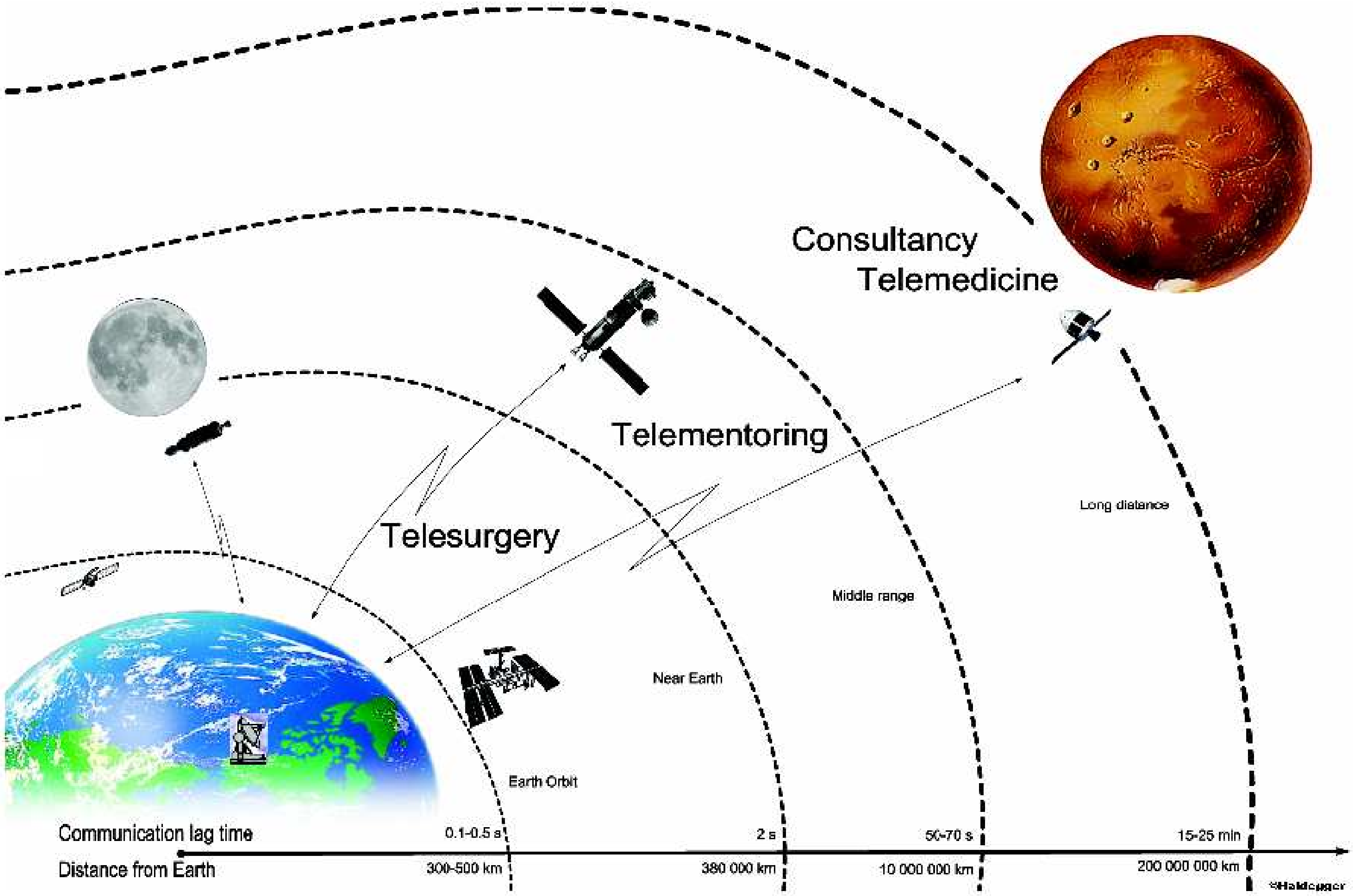
Identifying the difficulties

Communication over long distances

- Communication lag time (ms–min scale in the case of radio- and microwave transmission)
- Lack of adequate haptic control dealing with latency
- Special protocol is required (e.g. Space Communications Protocol Standards - SCPS)
- Broadband connection for video streaming (40 Mbps required for HD teleoperation)
- Automated robotic functions needed to improve human capabilities and safety
- Redundant transmission systems are necessary for smooth operation
- Behavior of organs and body liquids differs in weightlessness during surgical procedures

*R. Spearing, M. Regan: 4.0 NASA Communication and Navigation Capability Roadmap; Executive Summary, 2005

Concept of complete telemedical support

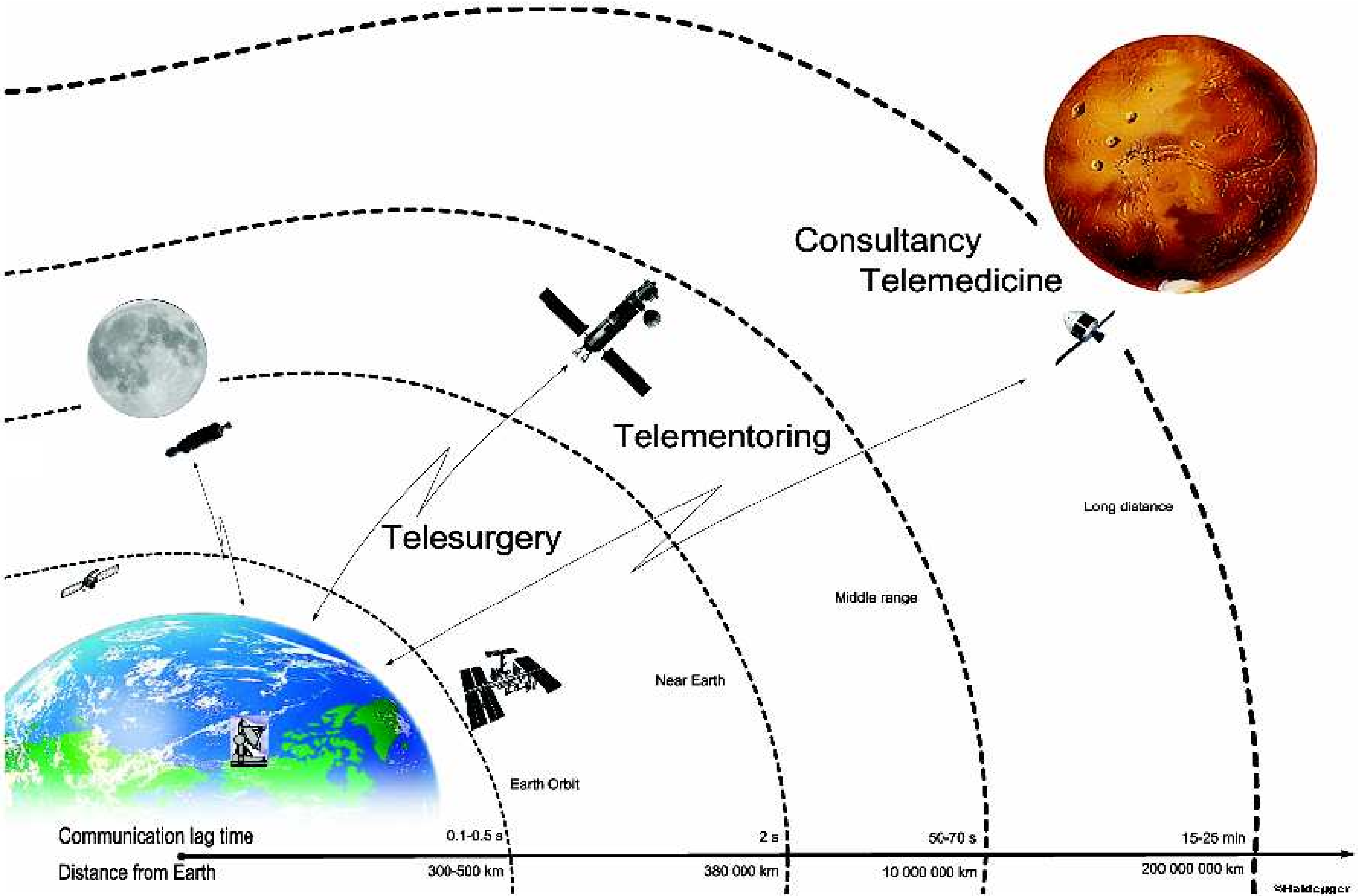


Concept of complete telemedical support

3-layered system architecture

- *Earth Orbit (Near Earth): Classic telesurgery*
  - App. within 380 000 km
  - Under 2 s signal delay
  - Excellent for ISS
- *Middle range: Telementoring*
  - App. within 10 000 000 km
  - Under 50-70 s signal delay
  - Permanent video contact with the ground
- *Long distance: Consultancy telemedicine*
  - Within the range of the Mars (200 000 000 km)
  - App. 10-40 min signal delay
  - Preoperative simulations and consulting

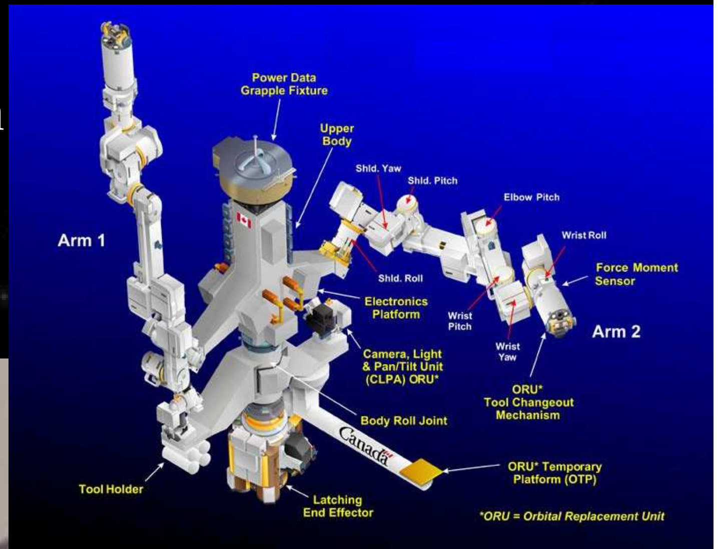
Concept of complete telemedical support



Terrestrial Spin-offs

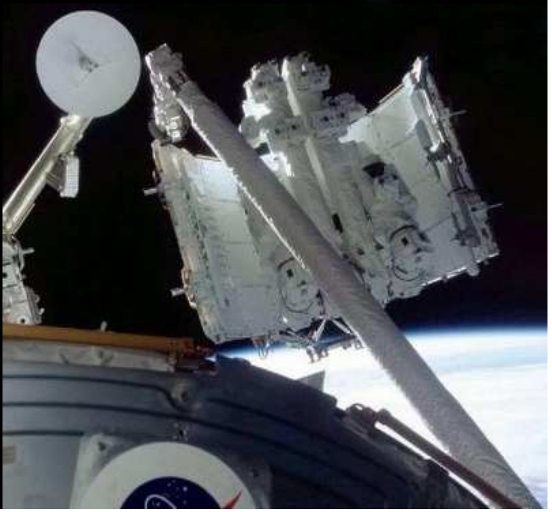
On Earth Applications

- Military use of Raven and M7 robots
- Advanced surgical simulators
- New human-computer interfaces
- Advanced control for teleoperation
- E.g. neuroArm: MRI guided robot for neurosurgery



Conclusion
Towards automated healthcare

- Surgical robotics is an effective tool for the health support of space missions
- The communication lag time causes significant difficulties in real time control
- Classic telesurgery can be effectively used on orbit and near Earth
- Telementoring may stay effective even with a minute of latency
- There is a significant need for more advanced automatic robotic functions, to improve human performance
- Alternative usage of the robots is required



*Images are courtesy of:
- National Aeronautic and Space Administration(NASA)
- Intuitive Surgical Inc.
- BioRobotics Lab.
- SRI International Inc.
- MD Robotics Inc.

Thank you for your attention!

Tamas Haidegger
haidegger@gmail.com

Full paper is available at:
www.eestec.hu/t/IAA_HinS_Haidegger.pdf