

Cyber-Physical Systems for Surgery

Blake Hannaford
Howard Chizeck

University of Washington



0930930 "CPS Small: Control of Surgical Robots: Network Layer to Tissue Contact".

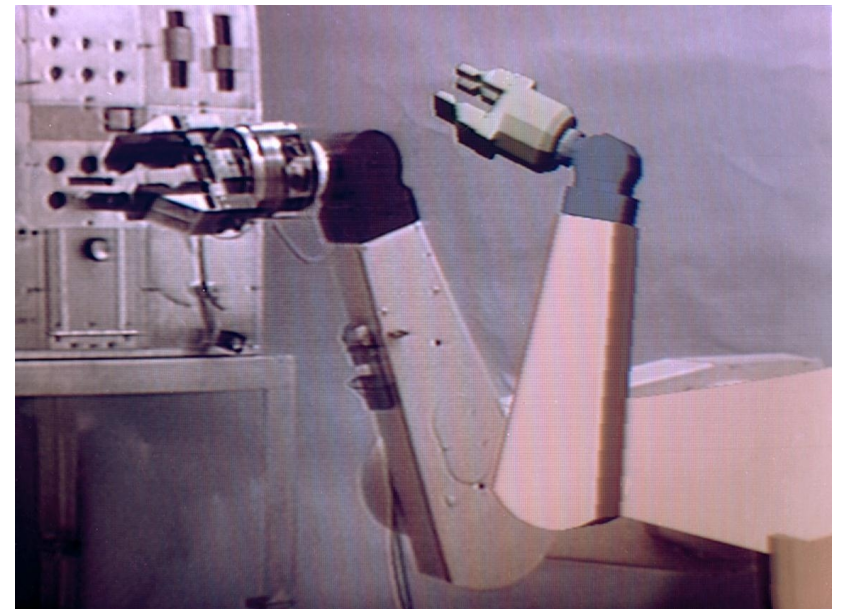
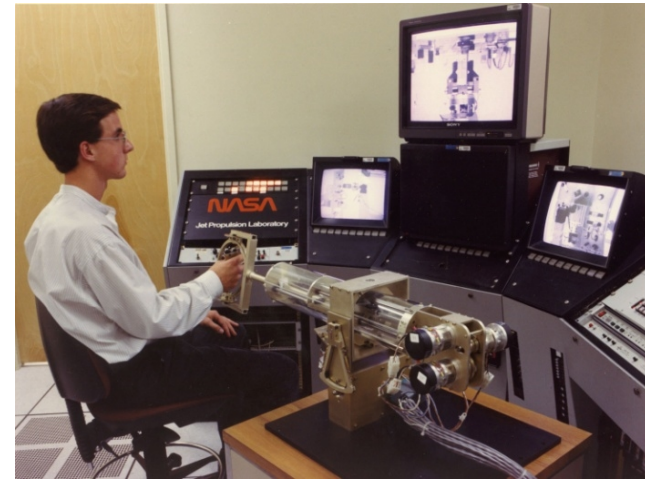
Outline

- Teleoperation and Surgery
- Human-Machine Control
- Tissue Aware Control
- Virtual Fixtures
- Raven – II
- Students:
 - Hawkeye King
 - Sina Nia Kosari
 - Srikrishan Ramdurai
 - Fredrik Reyden
 - Ruth Sims

Traditional Surgery



Traditional Teleoperation

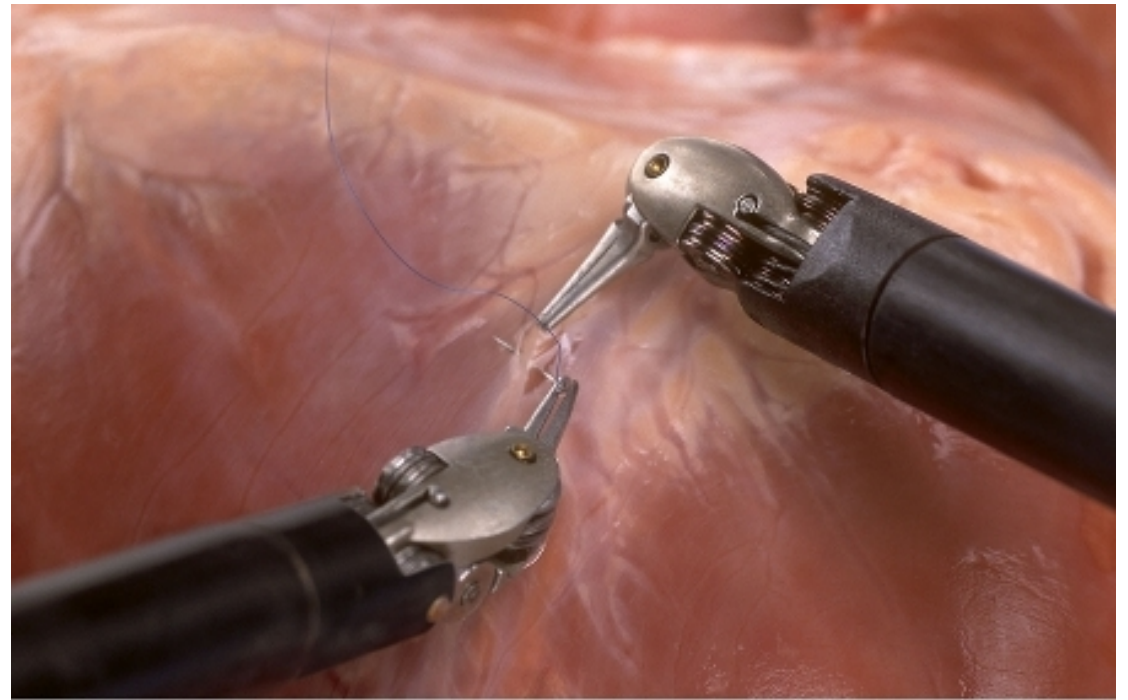
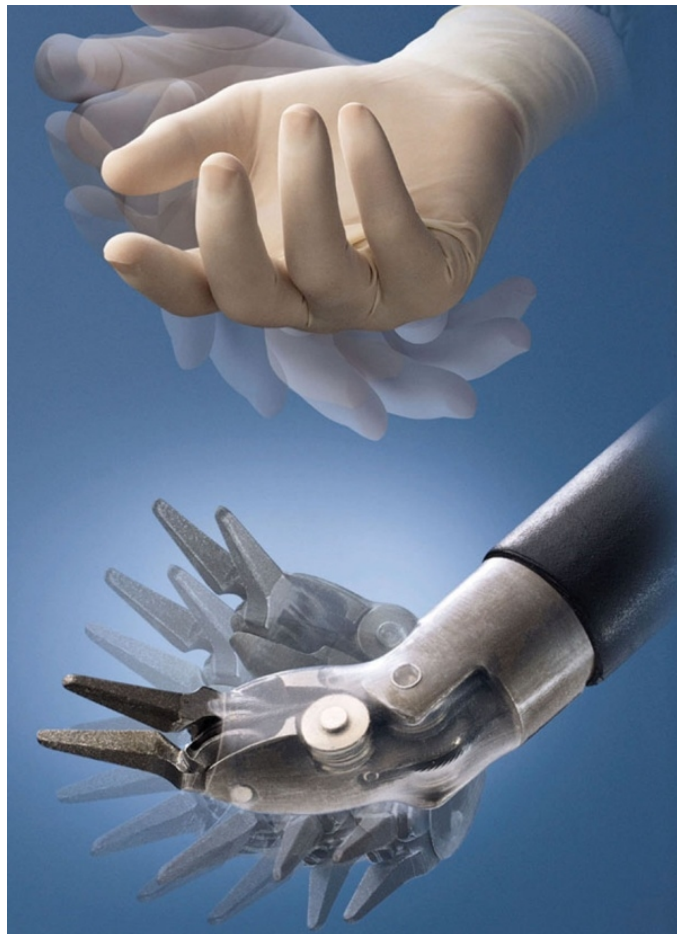


Today's synthesis

“da Vinci” Intuitive Surgical Inc.

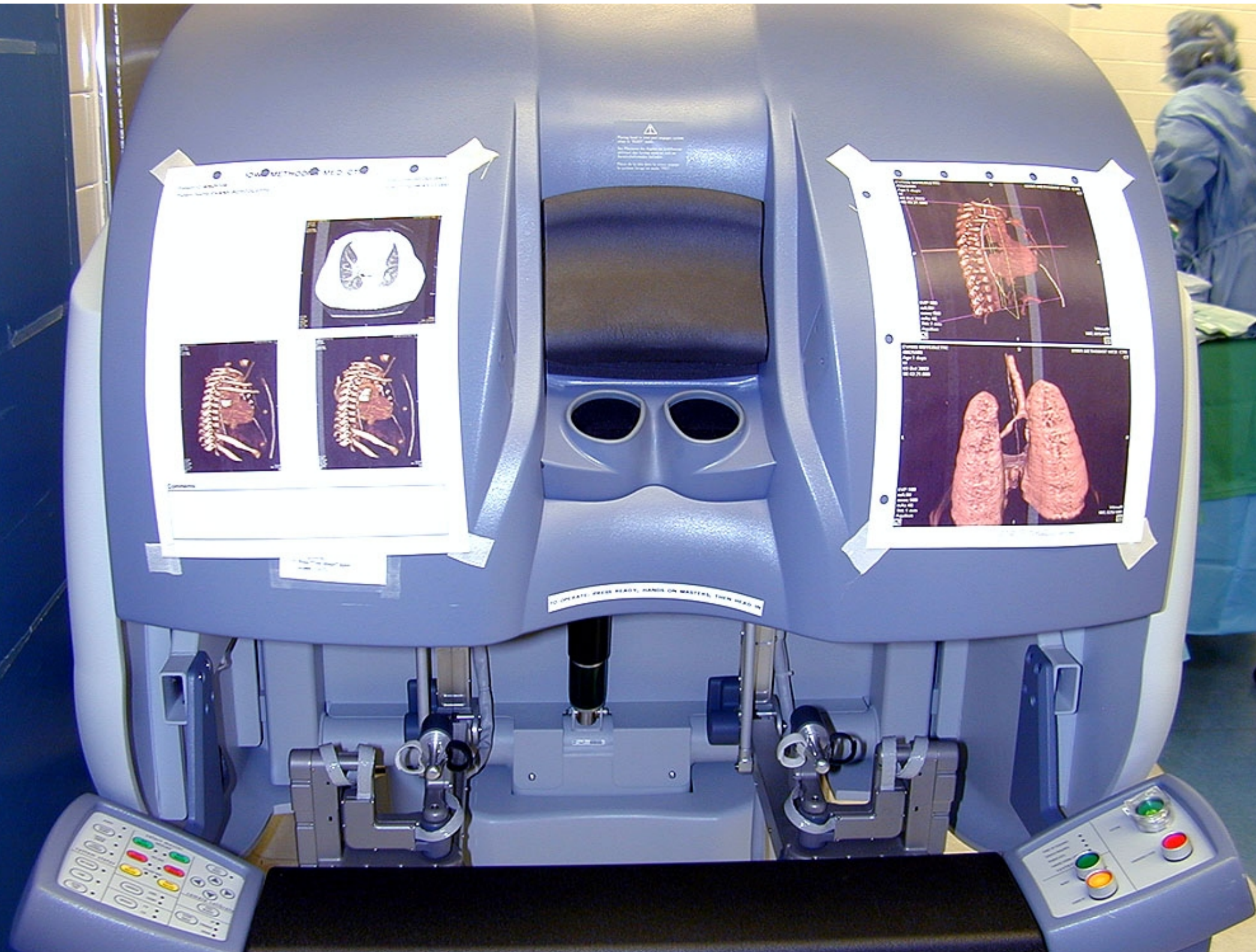


Physical and Human Interaction

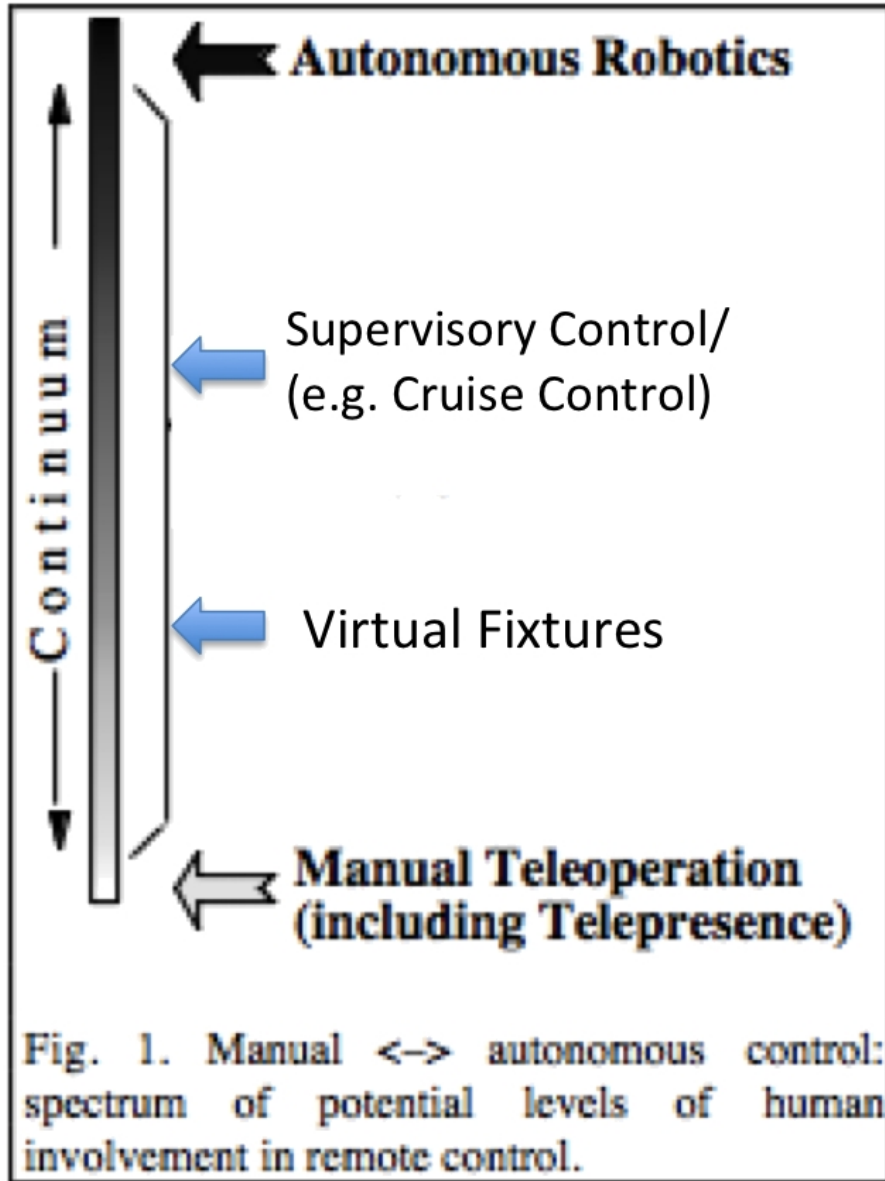


Medical CPS Technical Challenges:

- Imaging: Integrate pre-operative and intra-operative images with robotics and human control
- Safety and Effectiveness: *identifiable patient benefits*, fail-safe design, high-confidence computing, interoperability,
- Target specificity (destroy tumor and spare nerves)
- Interactions between manipulators and living biological tissues. Tissue-aware grasping control.
- Definition and quantification of *skill*.

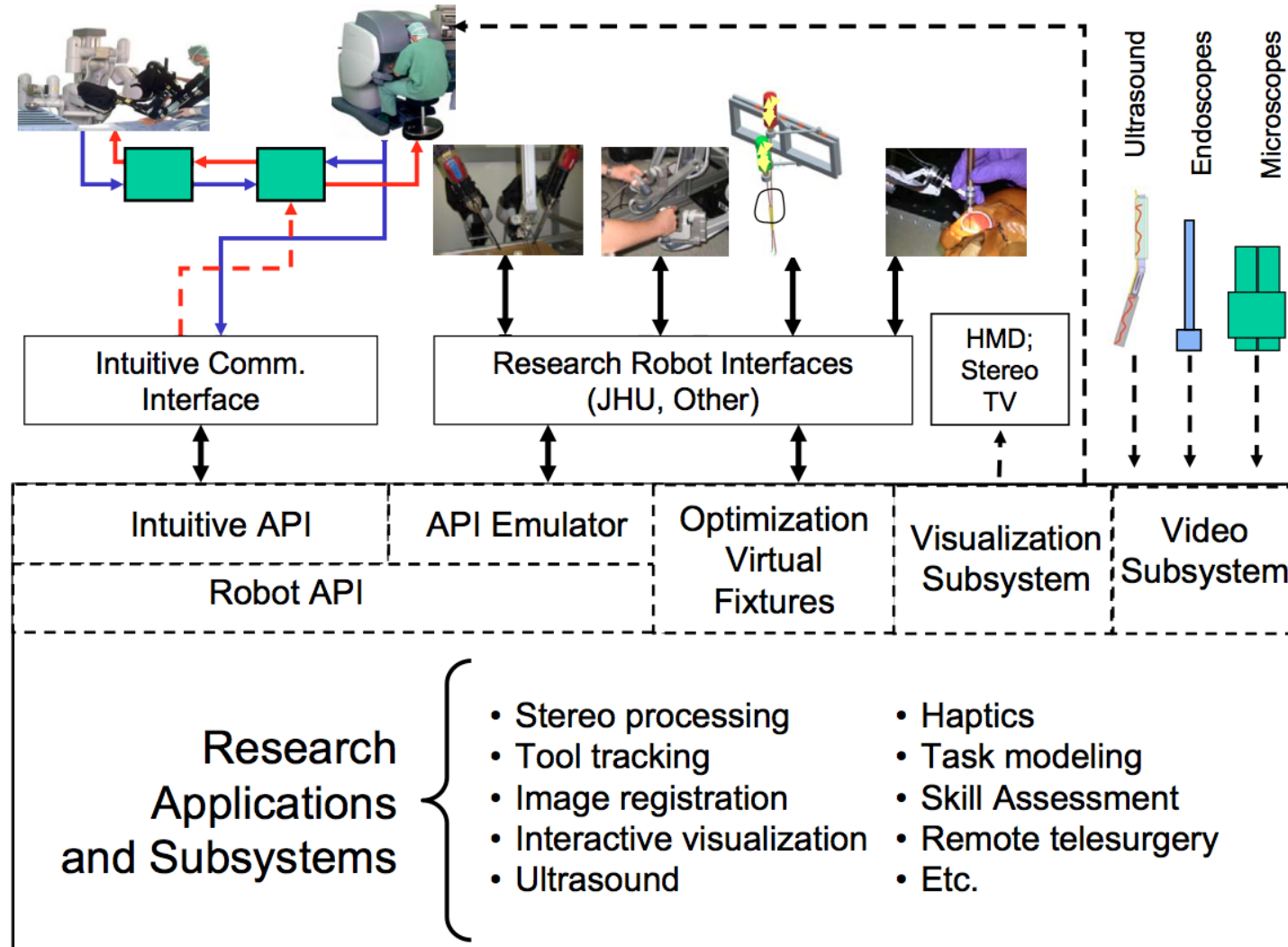


A continuum from Teleoperation ... Autonomy (Hager: HMCS)



Graphic: Paul Milgram, Shi Yin, Julius J. Grodski, *An Augmented Reality Based Teleoperation Interface for Unstructured Environments*, Proc. American Nuclear Society (ANS) 7th Topical Meeting on Robotics and Remote Systems, Augusta, Georgia, USA, April 27-May 1, 1997. pp. 966-973.

SAW – Surgical Assistant Workstation



R. Taylor, G. Hager, et al., Johns Hopkins

Tissue Aware Control

Dynamics of tissue

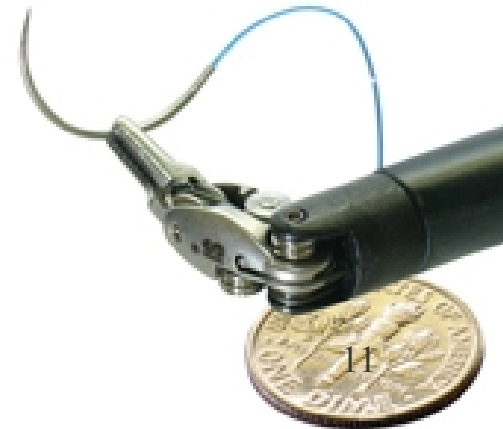
- Nonlinear tissue parameters
- Different from organ to organ and patient to patient
- Damage Thresholds

Lack of sensory information. Sensors are:

- Noisy
- Often expensive
- Require additional wiring
- Small enough?
- Sterilizable?

Parameter
Estimation

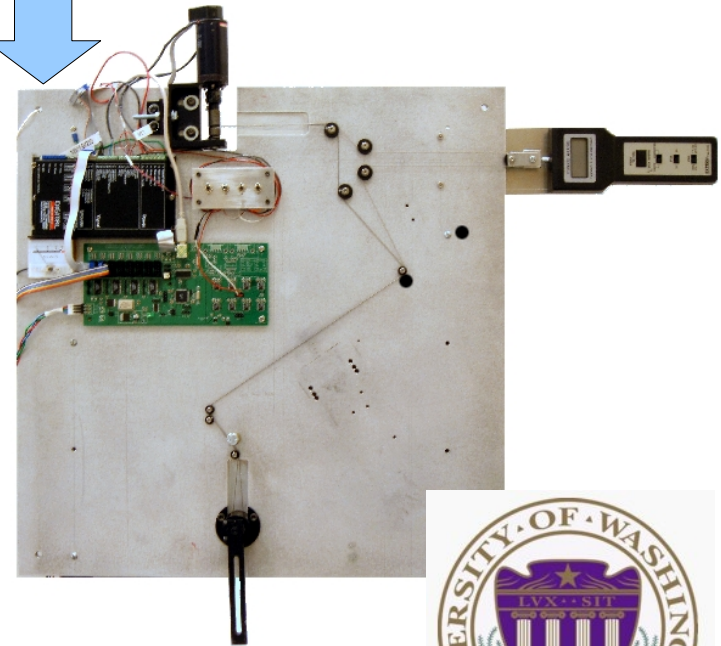
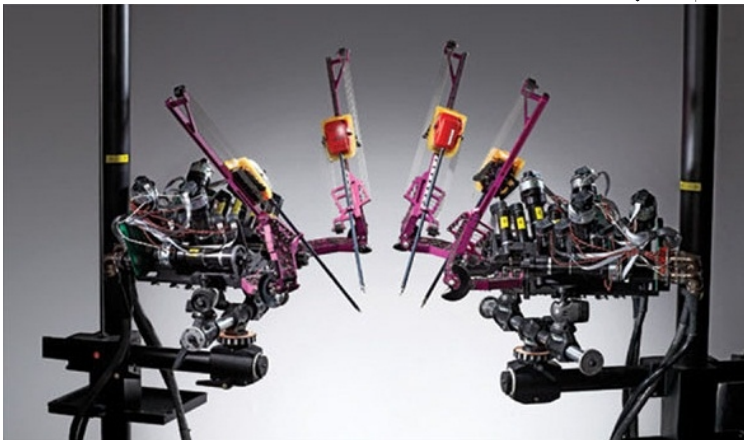
State
Estimation



Pullyboard testbed

Real-Time Controller
Unscented Kalman Filter
Model Reference Adaptive Control
Intelligent Teleoperation
R.O.S.

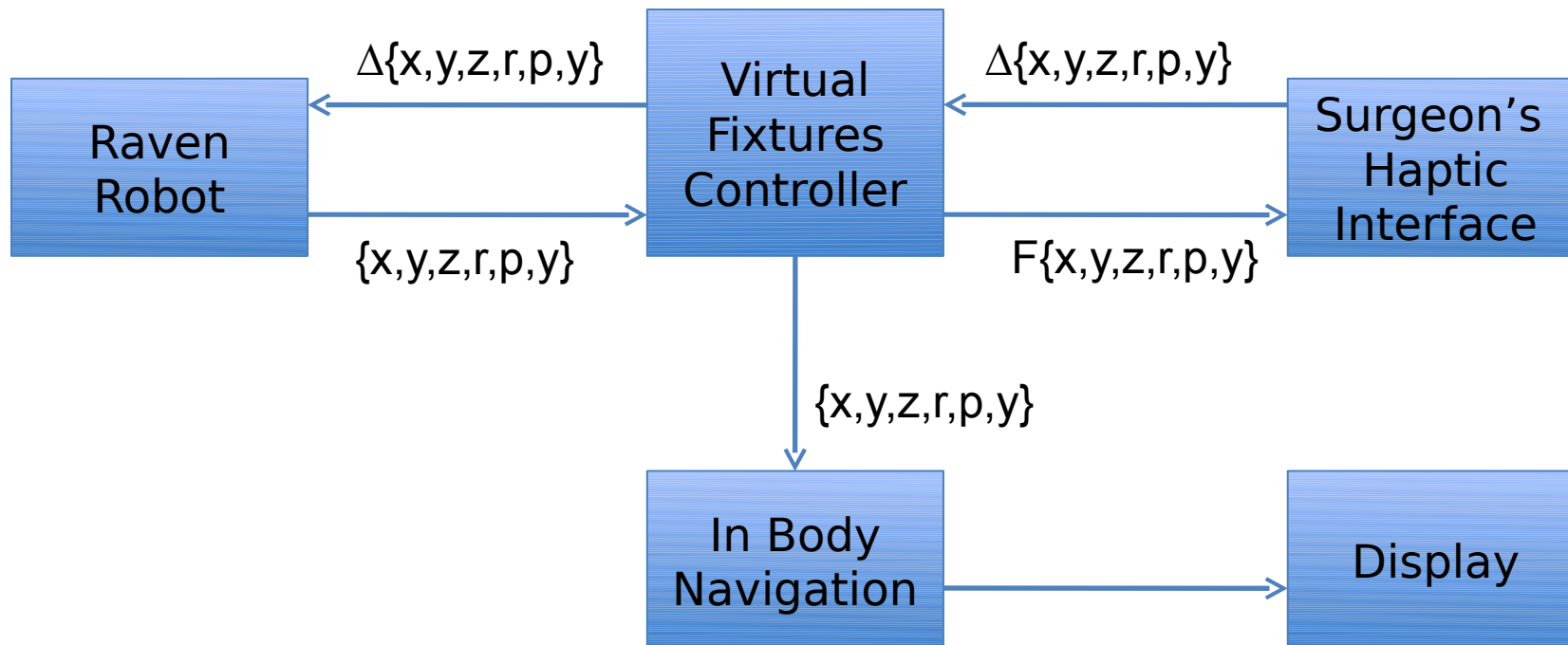
“Raven-II”



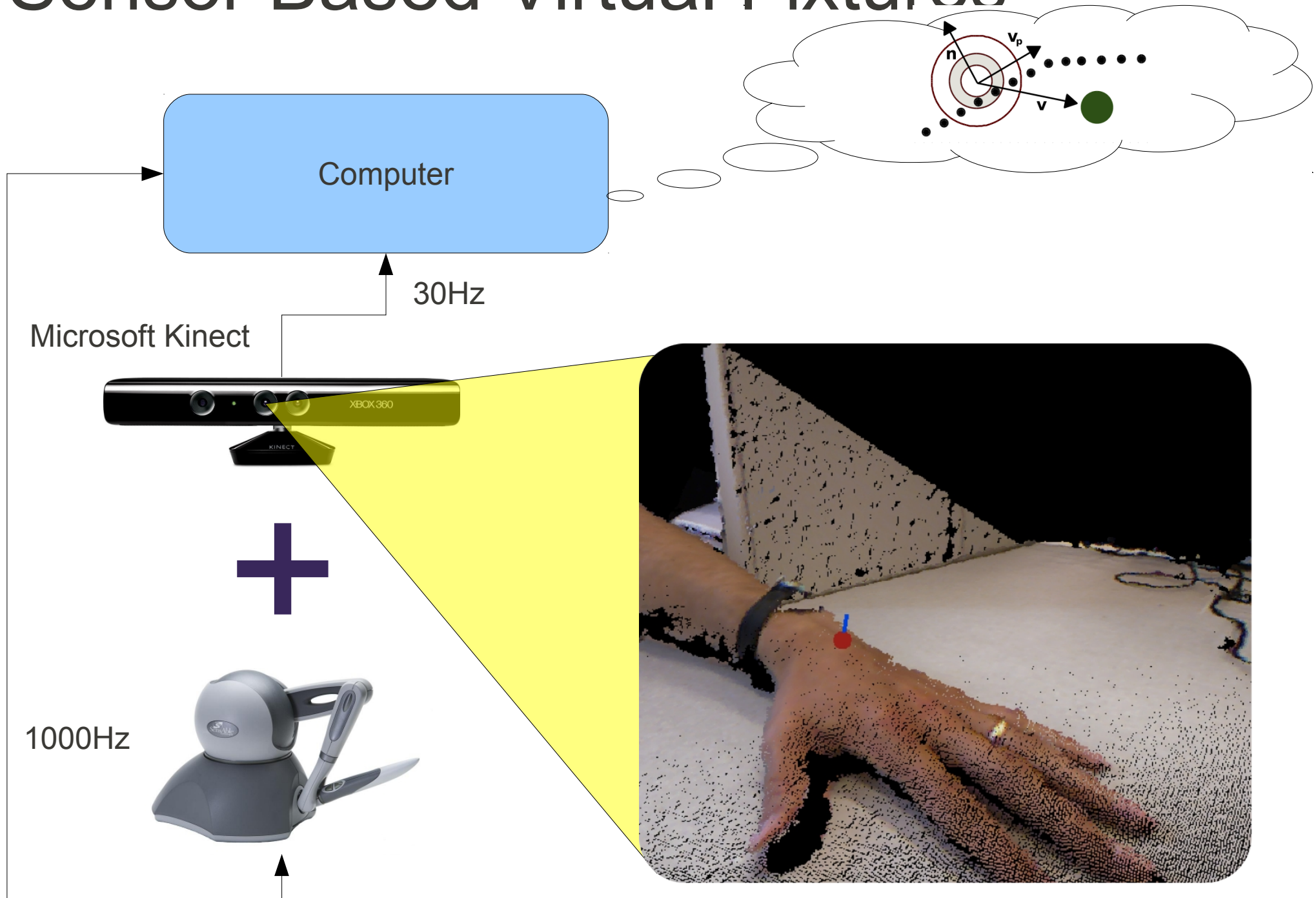
Jacob Rosen

Virtual Fixtures

- Near Term:

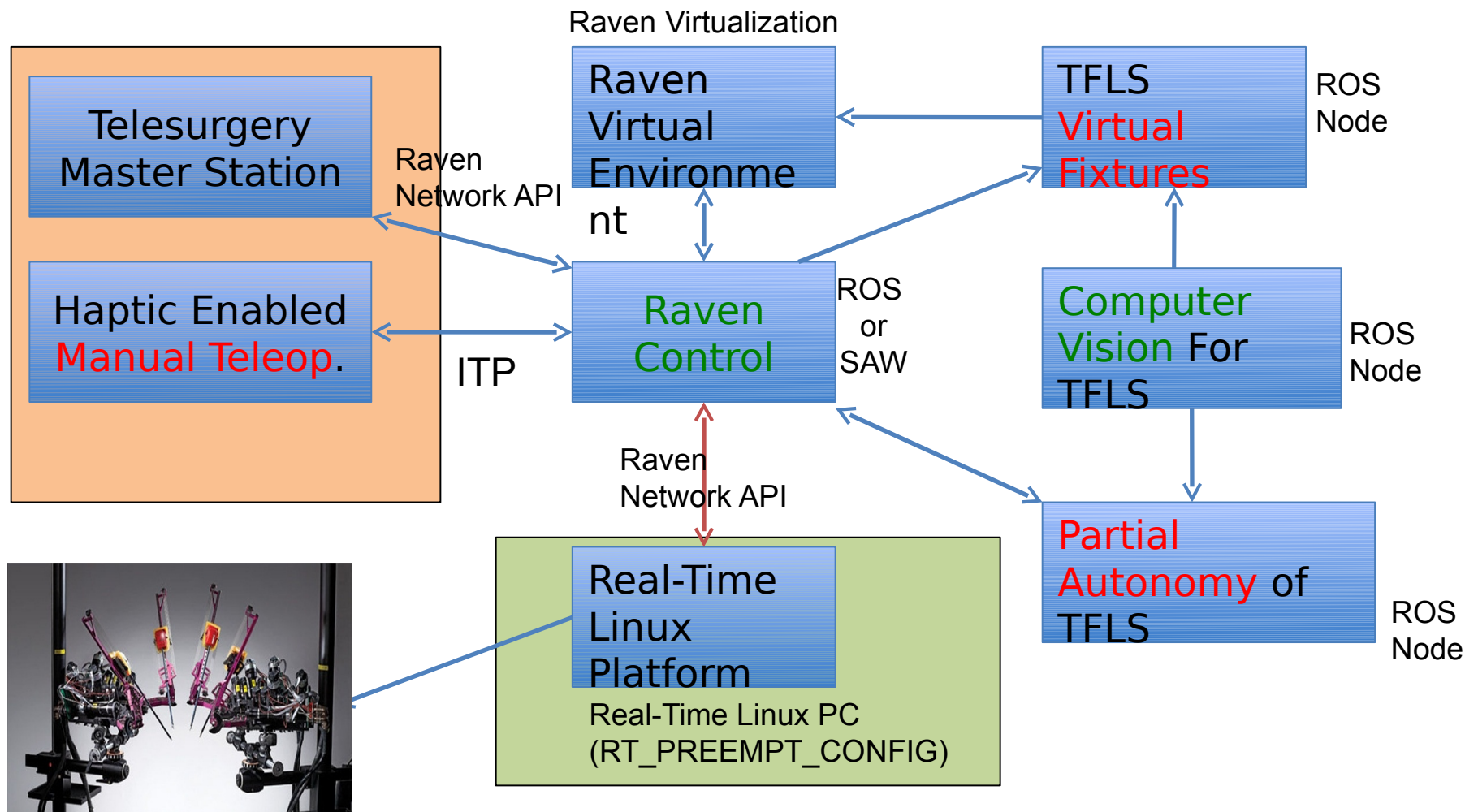


Sensor Based Virtual Fixtures



Virtual Fixtures

- Longer Term:



Raven-II

II-New: A Network of Open Testbeds for Surgical
Robotics Research

CNS-0958441



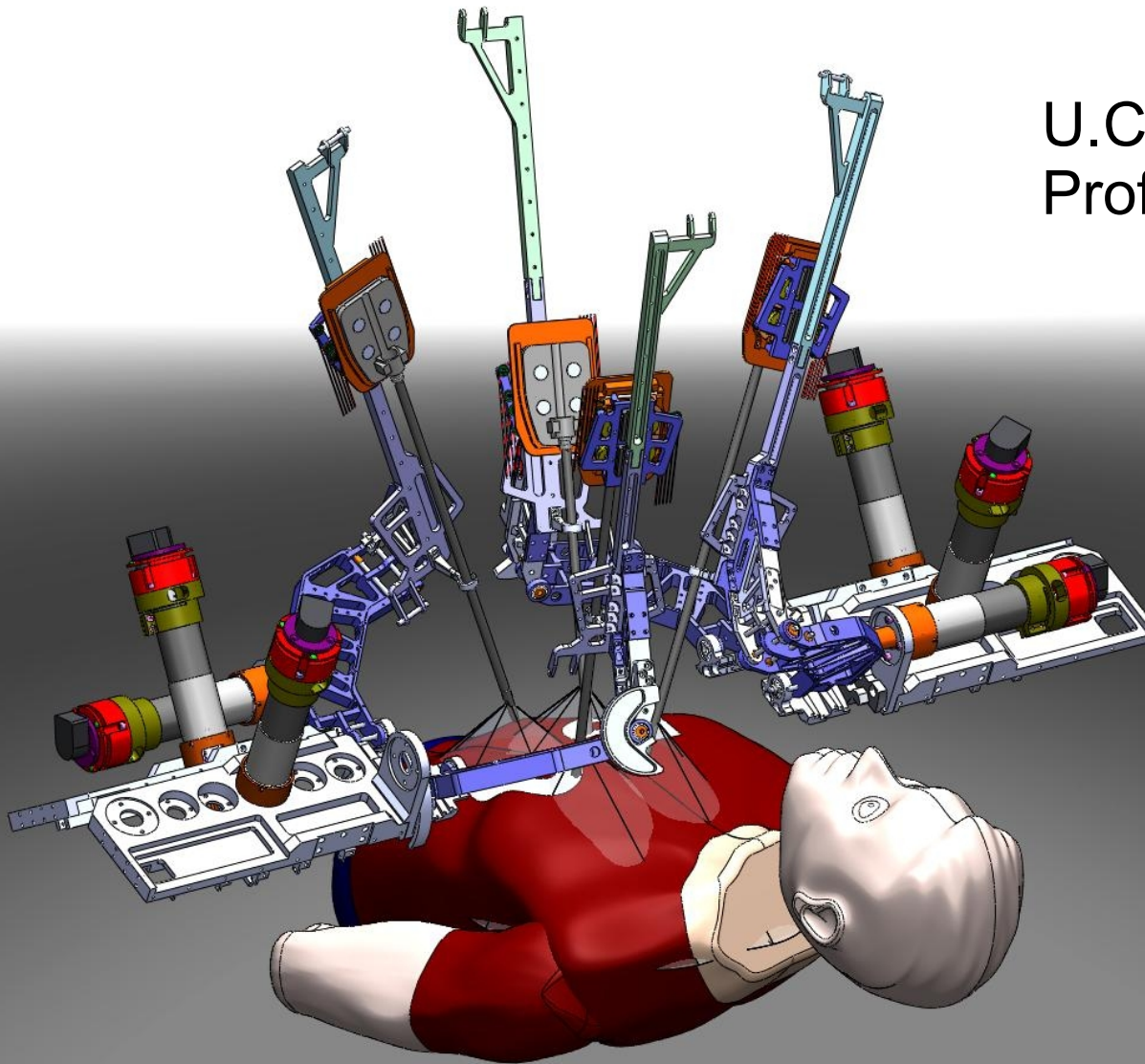
Goal

- Set up a network of open research telerobots for medical applications
- Build seven “Raven-II” systems
- Adapt software for easy collaborative development.

Sites:

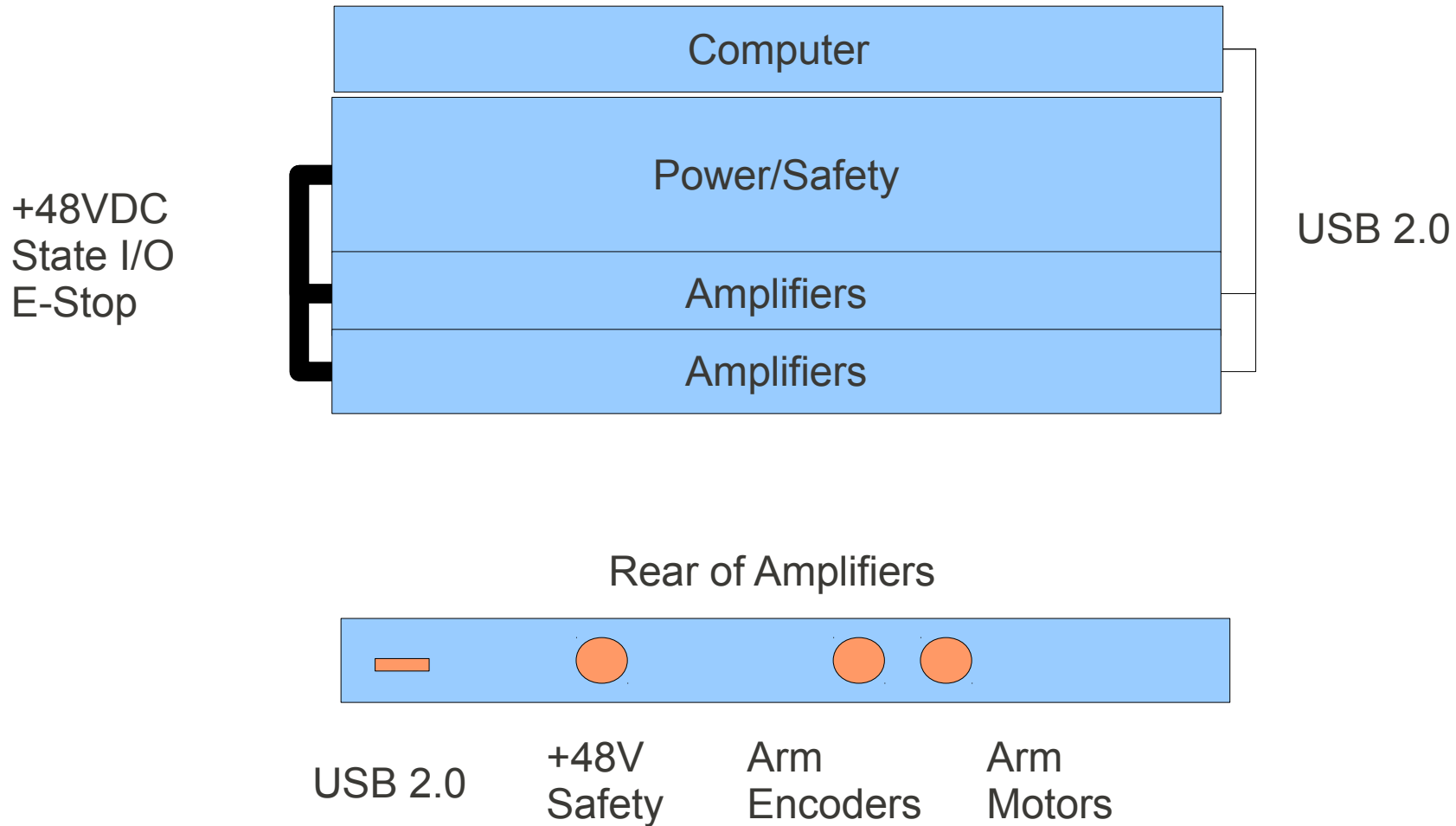
- Harvard University (Prof. Rob Howe)
- Johns Hopkins (Prof. Greg Hager)
- University of Nebraska (Prof. Shane Feritor)
- UCLA (Prof. Warren Grundfest)
- Berkeley (Prof. Pieter Abeel/Ken Goldberg)
- UCSC (Rosen)
- Washington (Hannaford)

U.C. Santa Cruz
Prof. Jacob Rosen

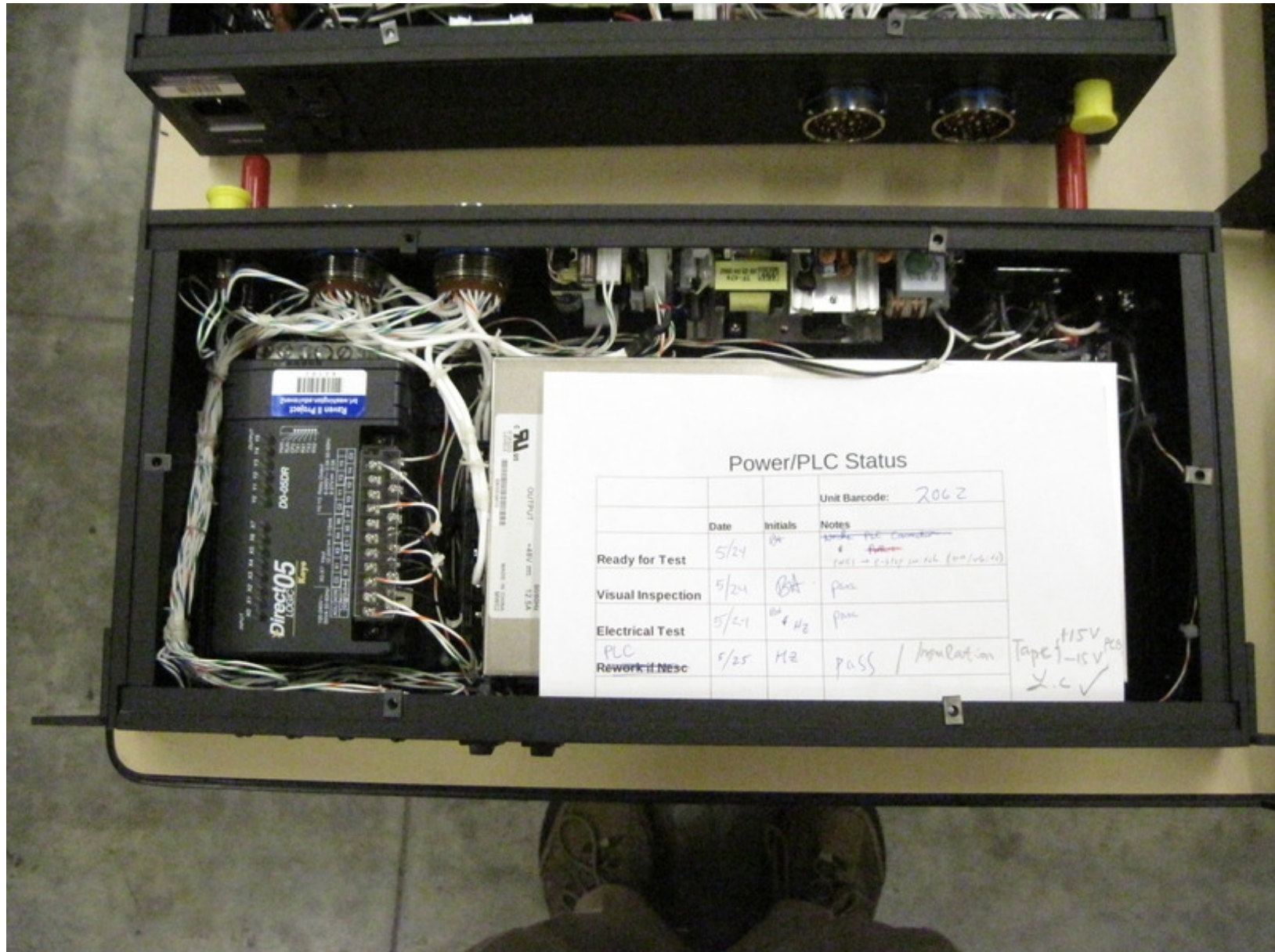




Electronics Stack



Power/Safety





Amplifier Box



Expected Delivery

Sept 2011(!)