An Open-Source Research Kit for the da Vinci® Surgical System

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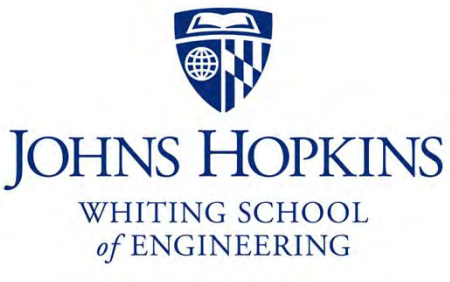
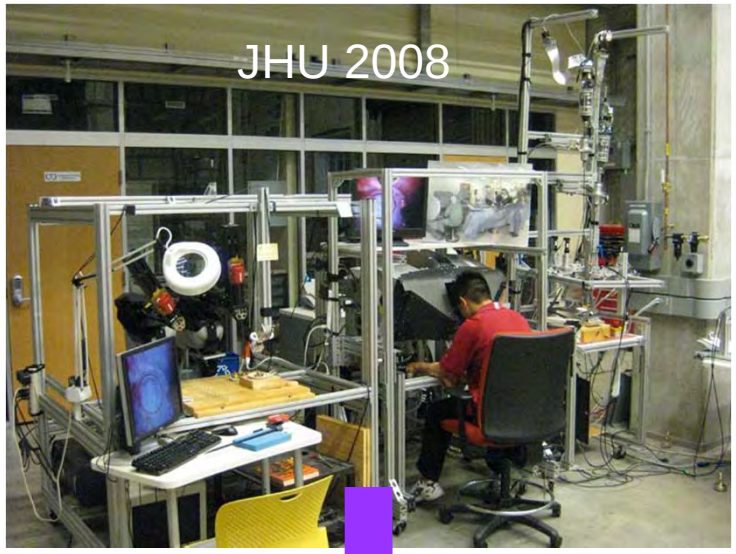


Outline

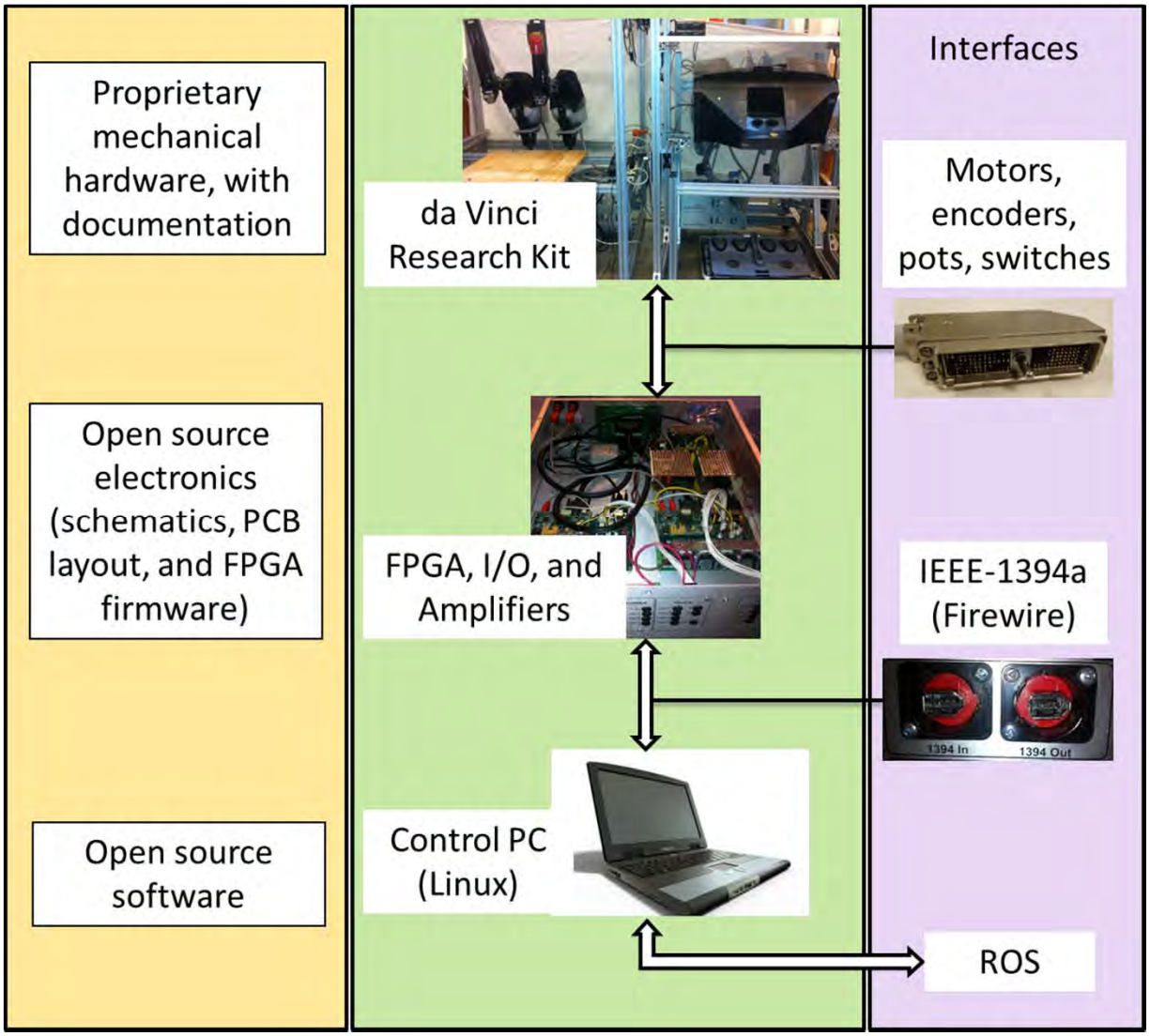
- Overview of da Vinci Research Kit
- Control architecture
- Open source mechatronics
- Open source software
- Community
- Interoperability
- Future outlook

da Vinci Research Kit



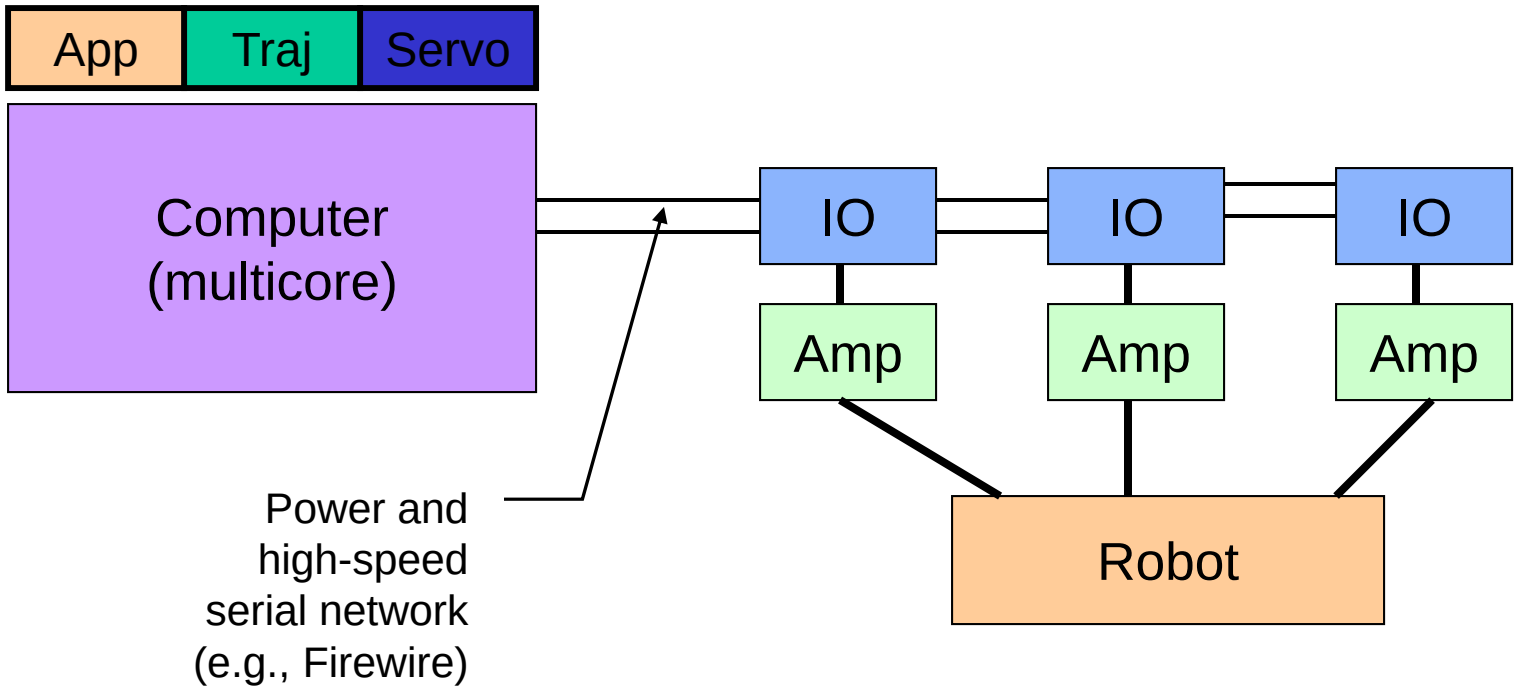
- Mechanical components from da Vinci "classic" systems
- Donated by Intuitive Surgical to selected university labs
- Consortium to provide "open source" engineering and support
  - Software – JHU (CISST/SAW)
  - Controller electronics – JHU
  - Interface electronics – ISI
  - Controller power/packaging – WPI
- Controllers and software also adapted for use with complete recycled da Vinci "classic" systems
- **http://research.intusurg.com/dvrkwiki/**

da Vinci Research Kit



DVRK Video

Robot Control Architecture: Centralized Computation and Distributed I/O



- Possible with high-performance networks/computers
  - All the benefits of distributed I/O (reduced cabling)
  - Computation on familiar development platform (flexibility)

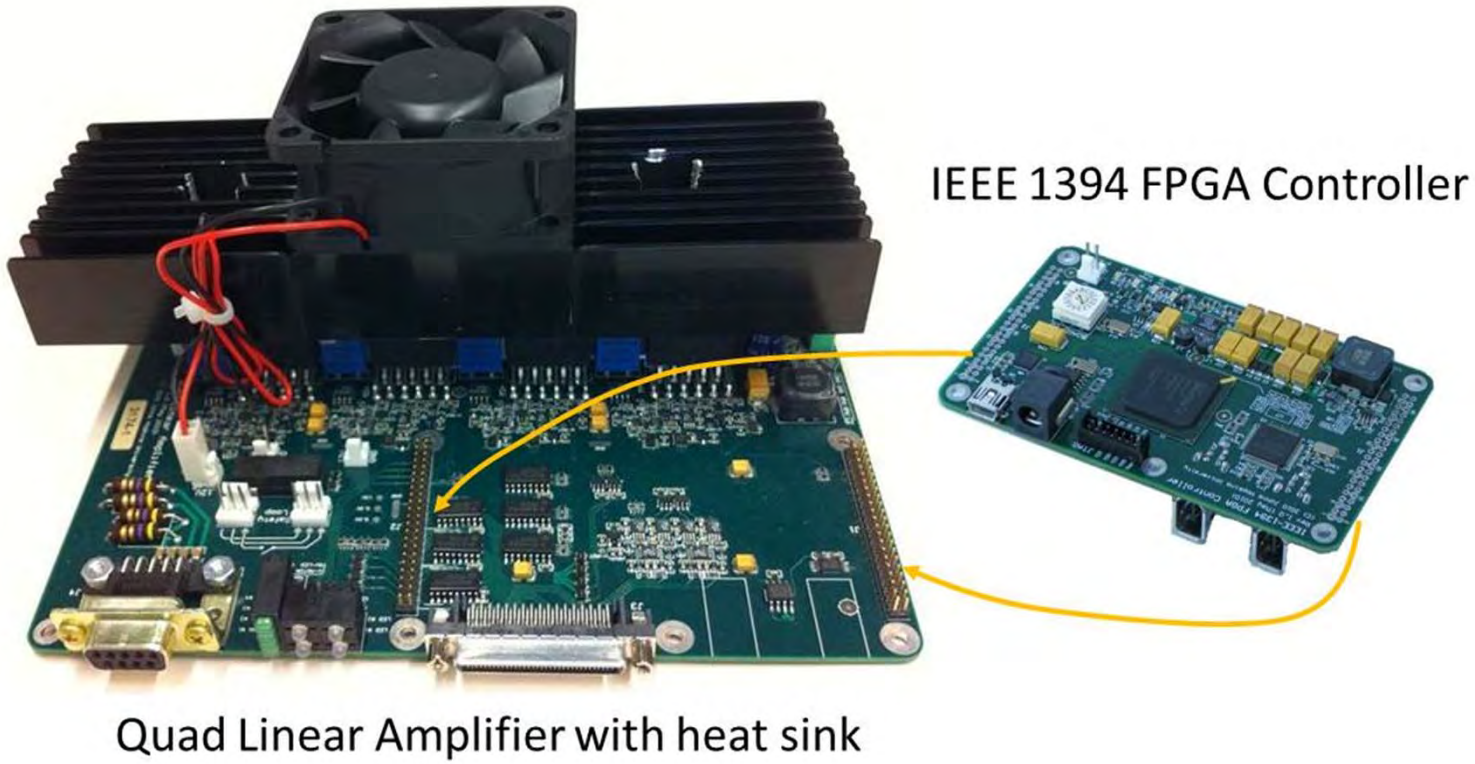
Serial Network Requirements

	IEEE-1394a (FireWire)	EtherCAT
• Speed of at least 100 Mbits/sec	✓	✓
• Low latency (tens of µsec)	✓	✓
• Ability to daisy-chain	✓	✓
• Readily available	✓	✓
• Simple FPGA implementation	✓	?
• Option for high-flex cabling	✗	✓

In 2006, FireWire appeared to be best choice

Today, other good options, such as EtherCAT

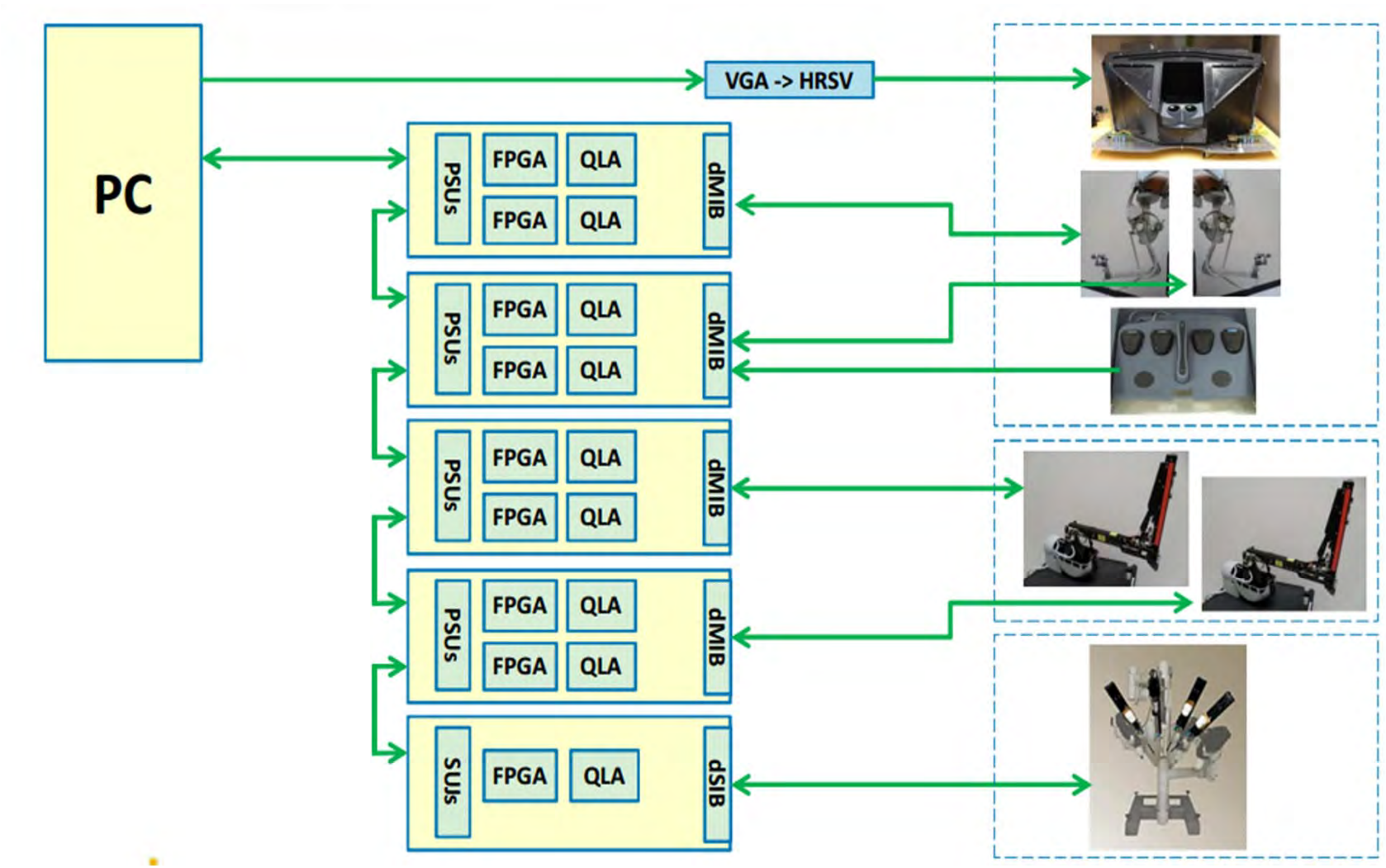
Open Source Mechatronics



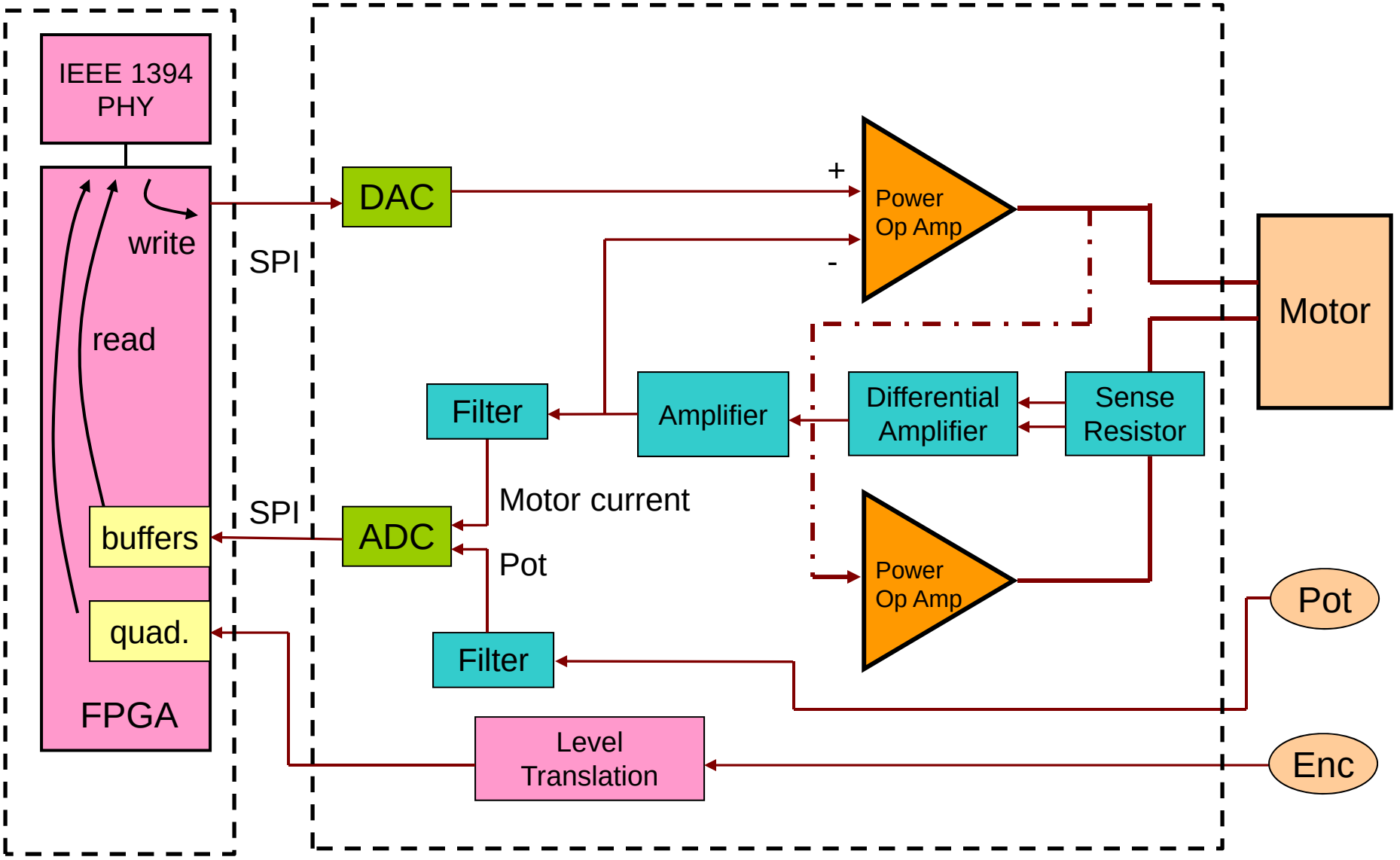
Open source: http://jhu-cisst.github.io/mechatronics/

- Schematics, PCB layout, firmware (Verilog)

da Vinci Research Kit



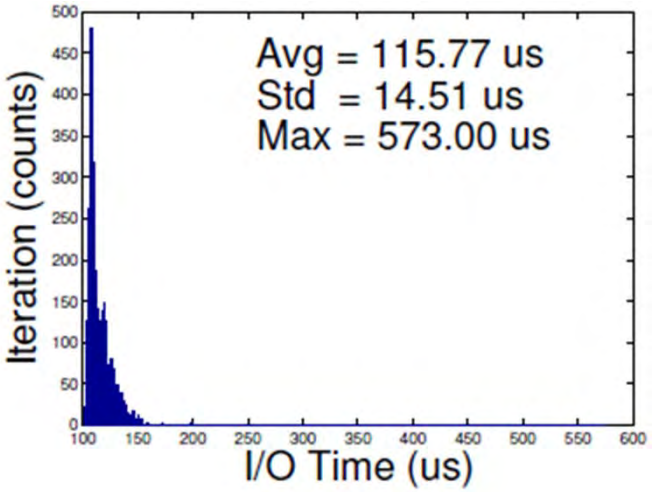
Hardware Block Diagram

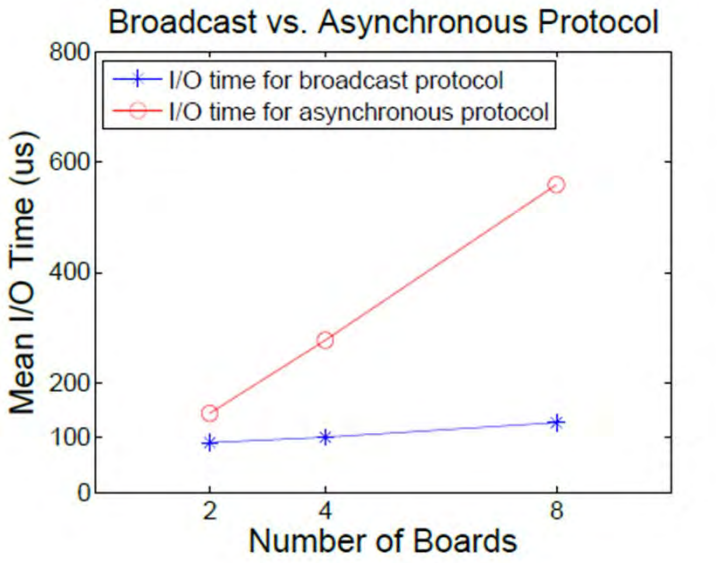


Control Performance

- Latency primarily due to overhead on PC
  - ~35 µs per asynchronous transaction
  - Individual read/write to 8 boards: ~530 µs
  - Taking advantage of broadcast and peer-to-peer transfers reduces I/O to ~116 µs

Broadcast protocol, 8 board sets

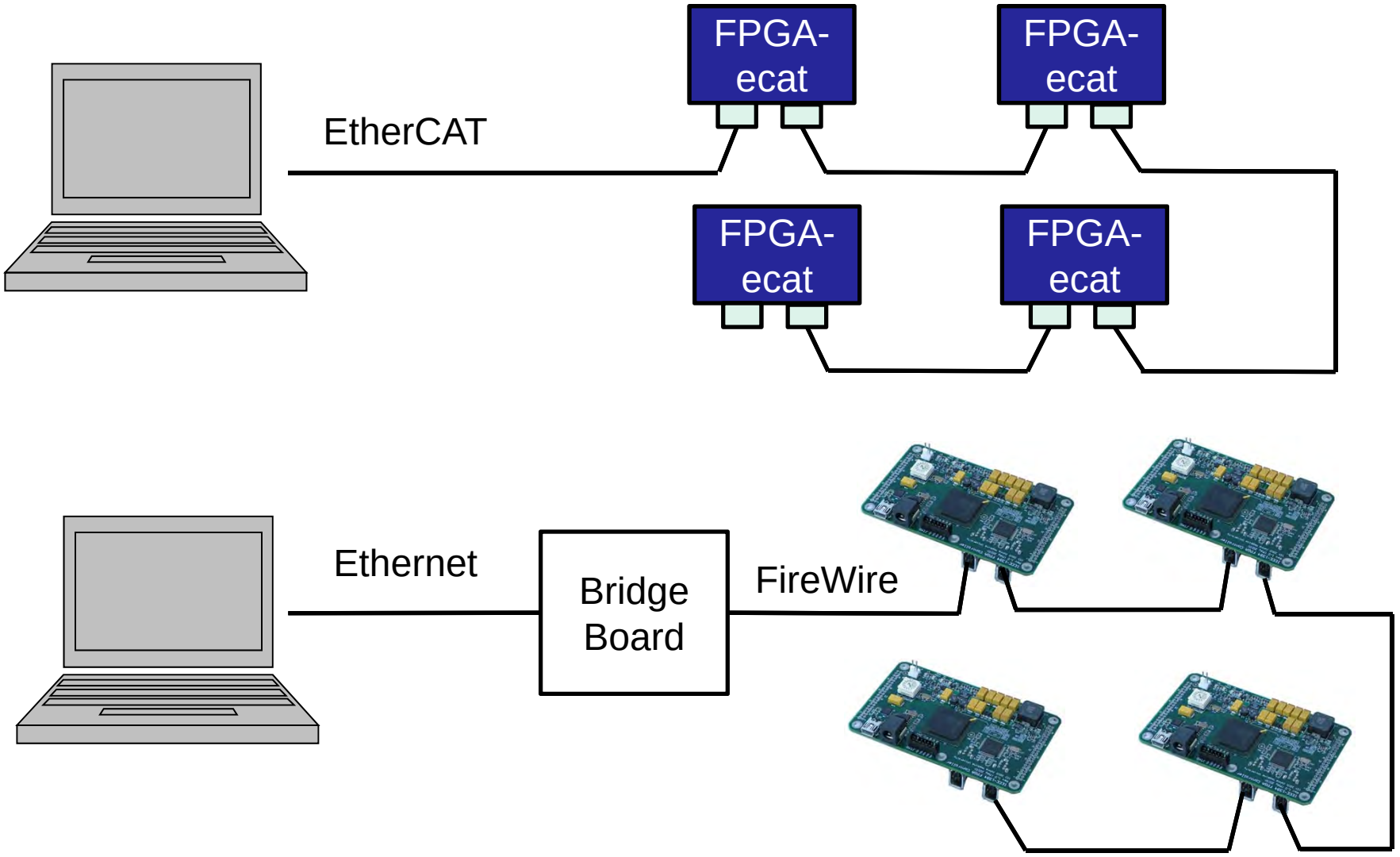




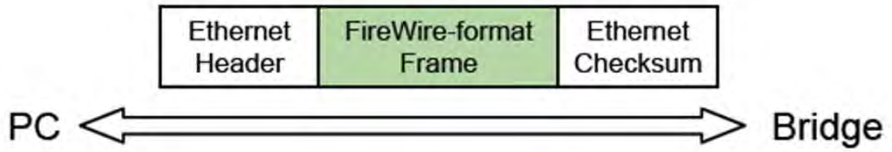
Hardware Revisited

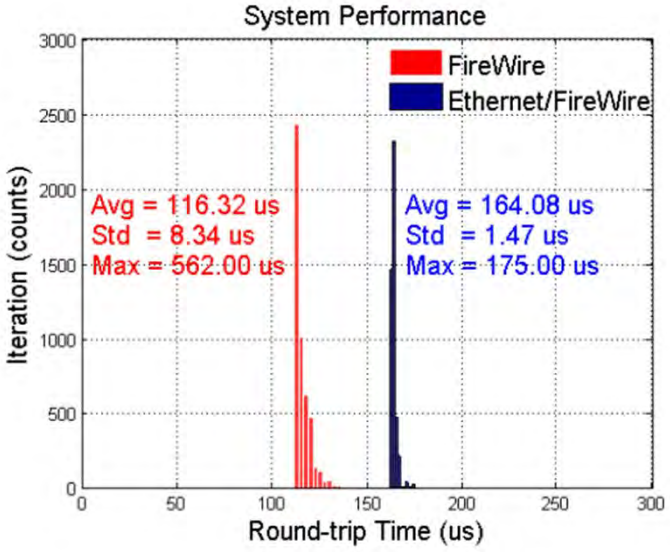
- In 2006, FireWire (IEEE-1394) seemed to be a good choice, but less common today than Ethernet
  - Most desktops and laptops contain Ethernet port
  - Linux has good low-level support for FireWire (libraw1394); other platforms do not
  - Development environments, such as Simulink Real-Time (formerly Matlab xPC) and Labview CompactRIO, support Ethernet, but not FireWire
  - Real-time driver for Ethernet available (RTnet); RT-Firewire no longer supported
  - EtherCAT uses standard Ethernet hardware on master, with custom slave hardware to enable daisy-chaining

Ethernet Alternatives

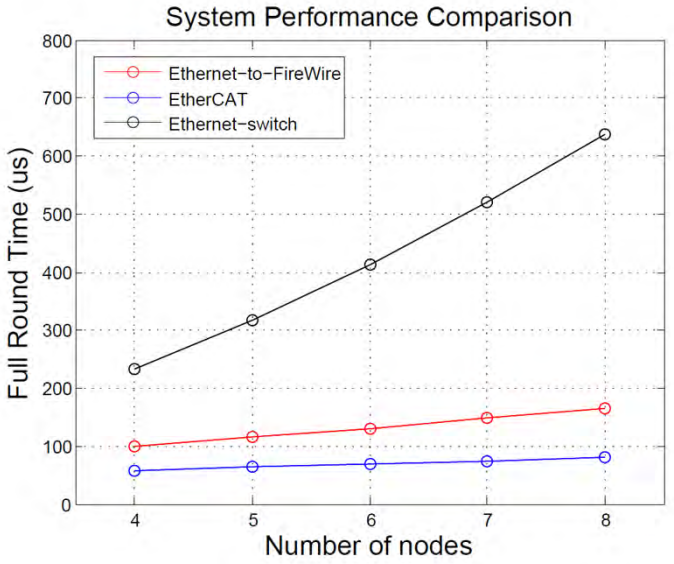


Ethernet-FireWire Bridge Performance



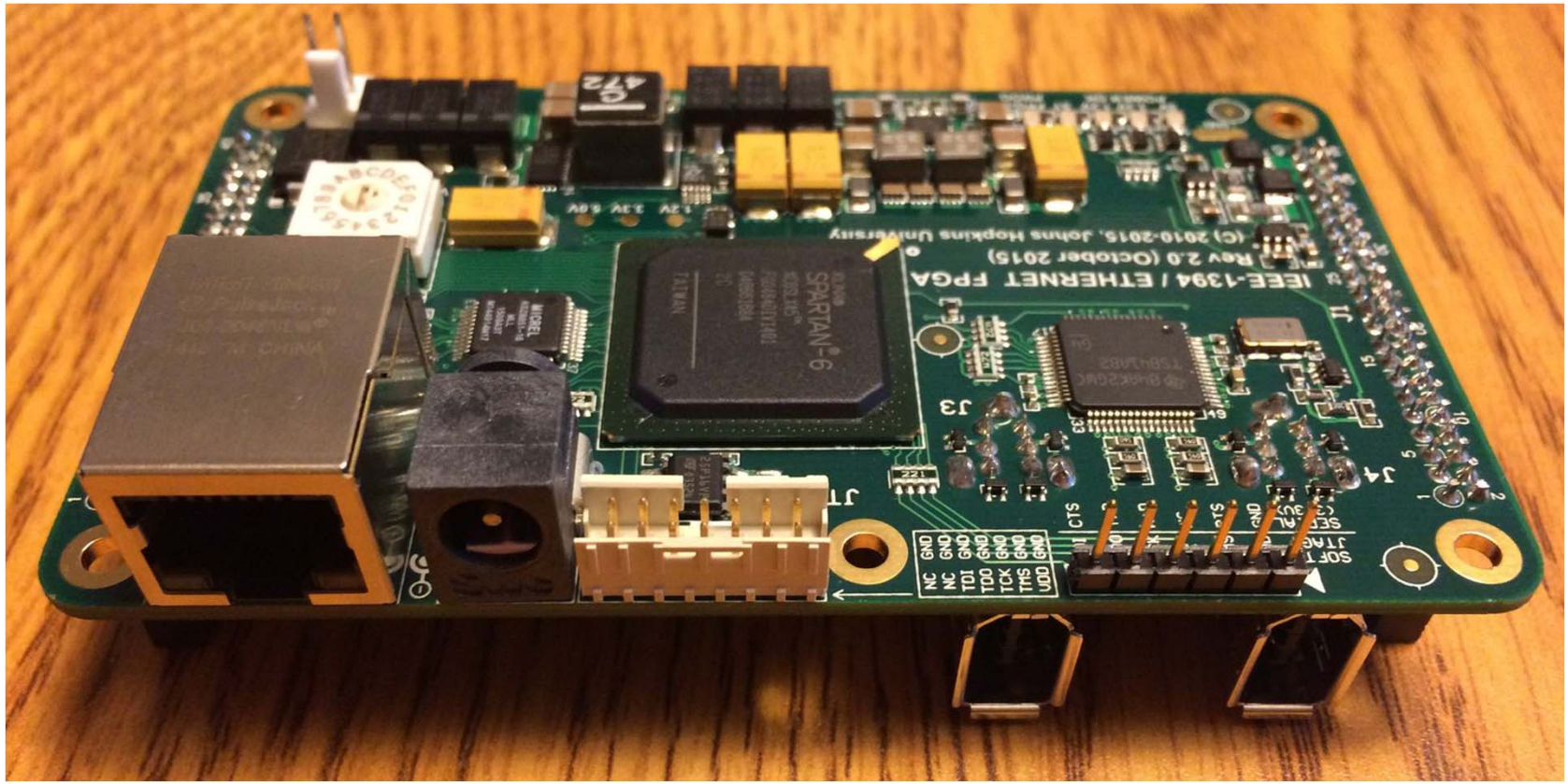


Measured performance on 8-node system (DVRK)

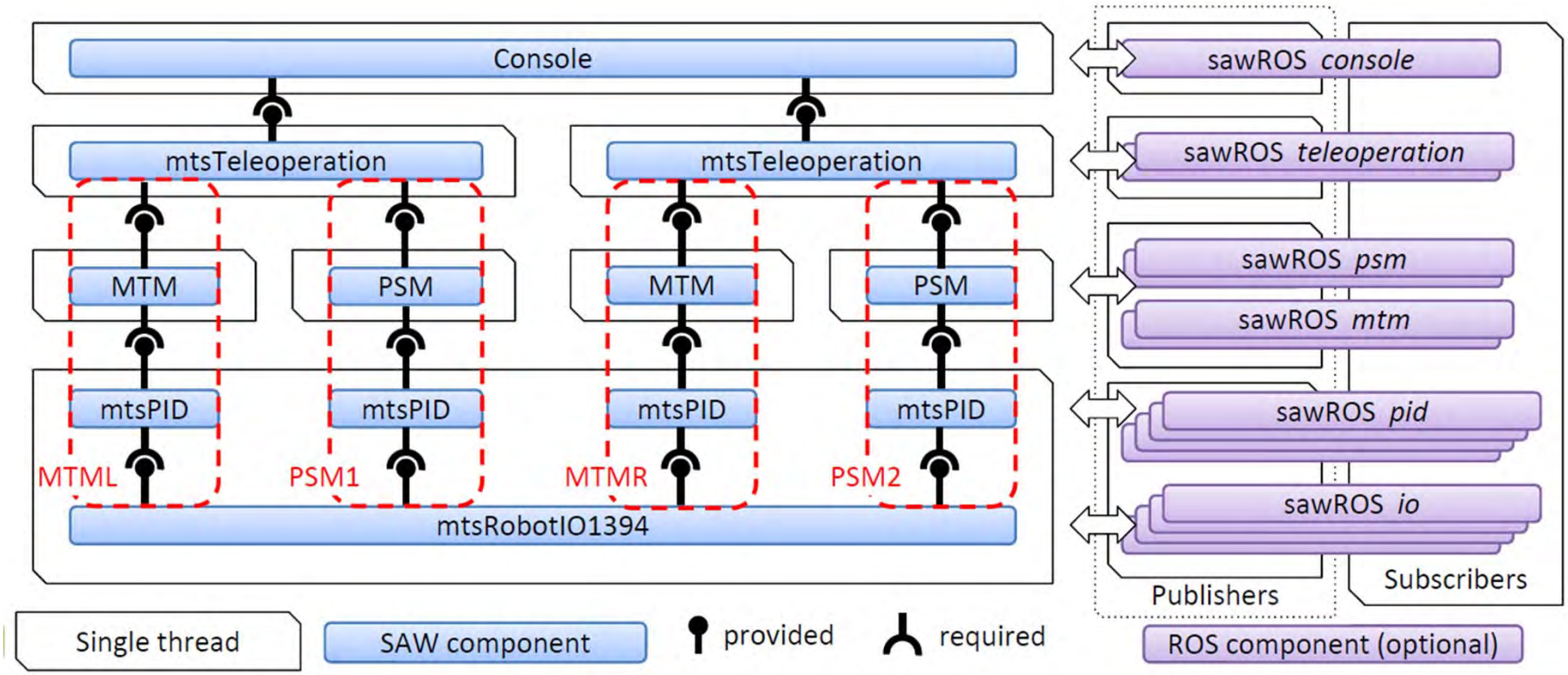


Analytical performance comparison

Ethernet-FireWire Design

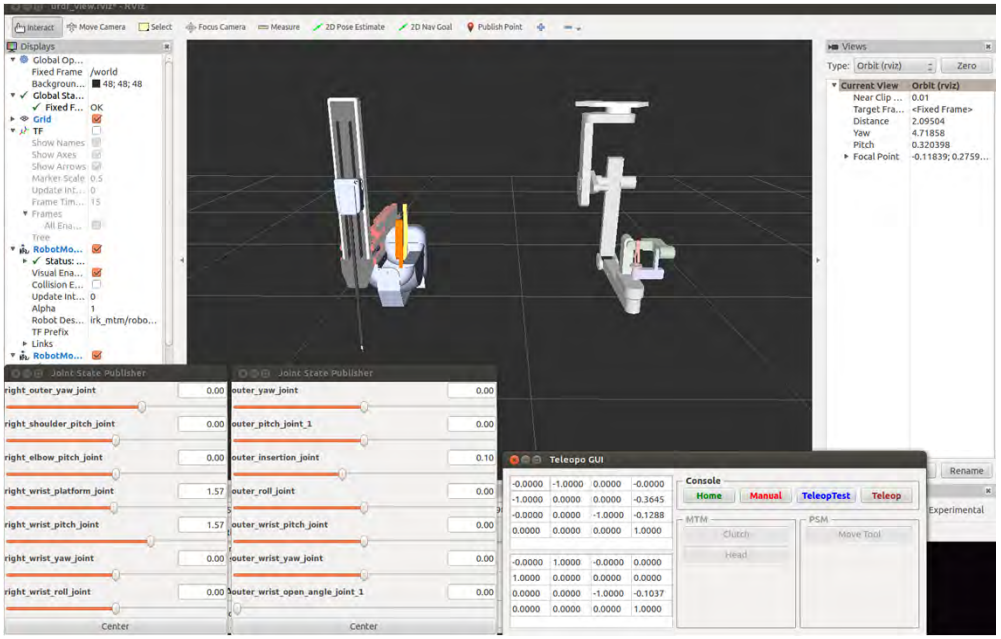


da Vinci Teleoperation (with ROS)

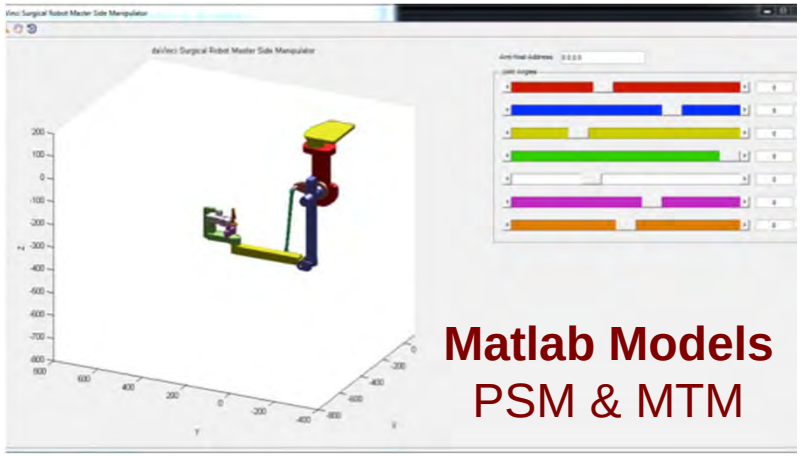


Simulation/Visualization

ROS/rviz



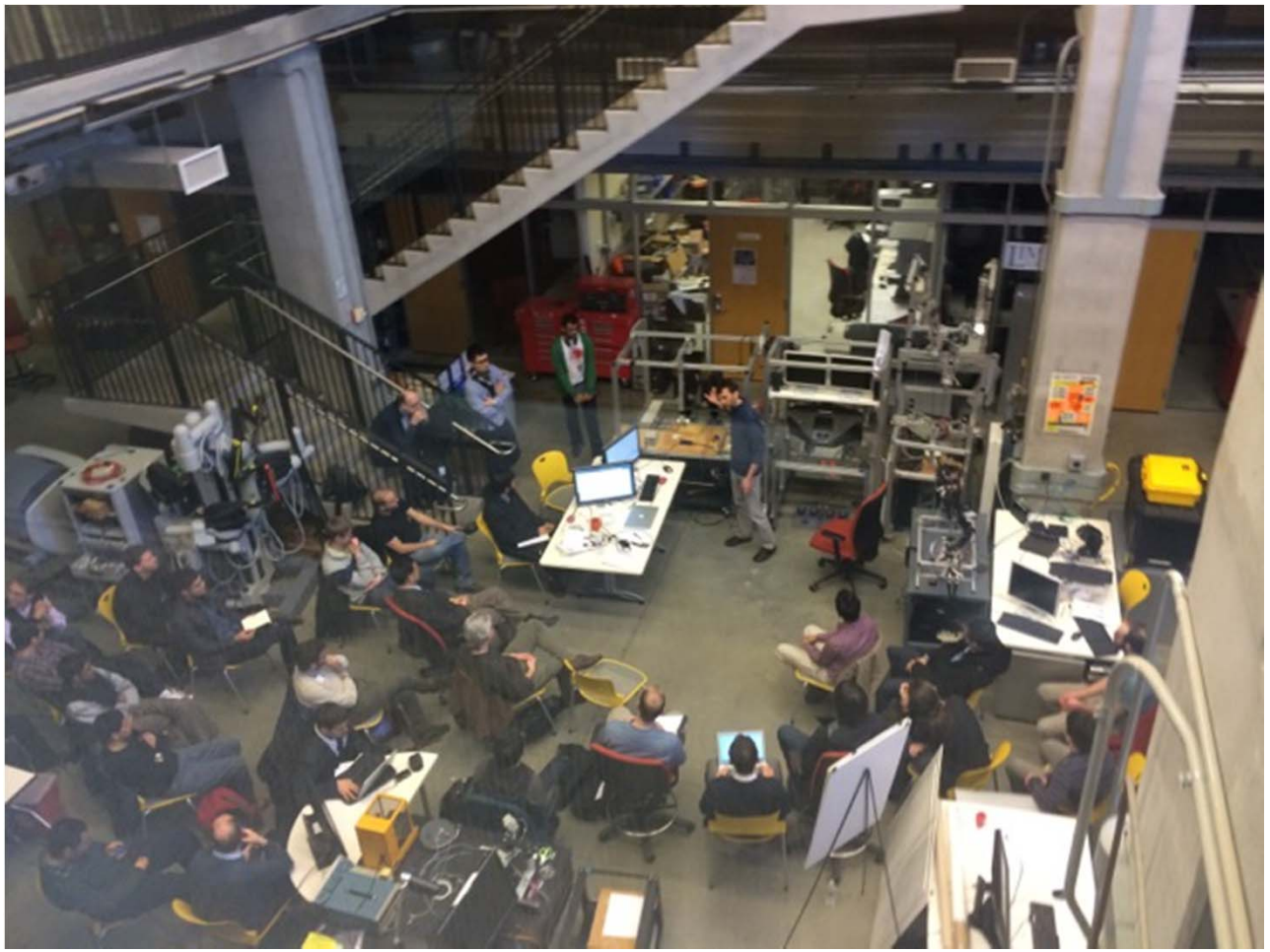
Gazebo Model
Dynamic Simulation



Matlab Models
PSM & MTM

User Community

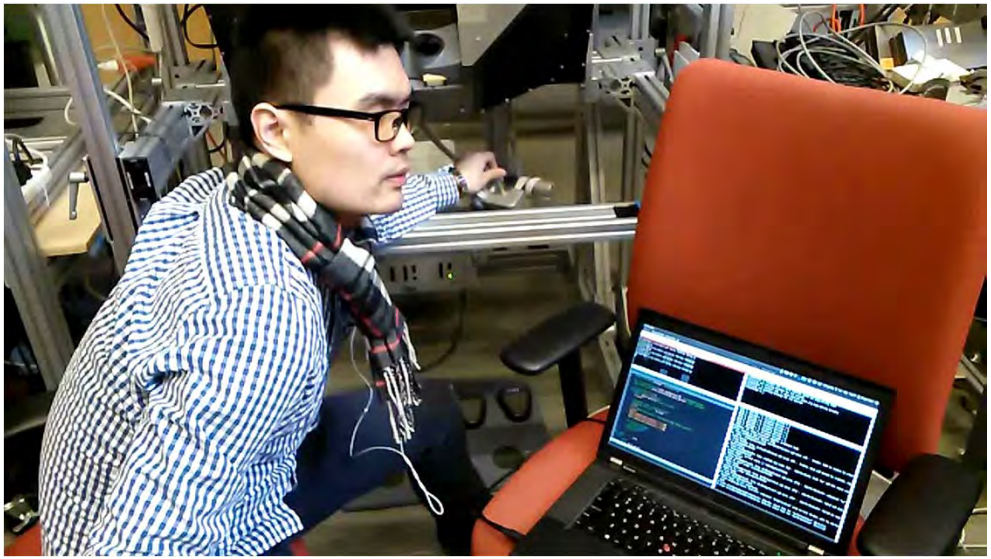
First DVRK User Group Meeting

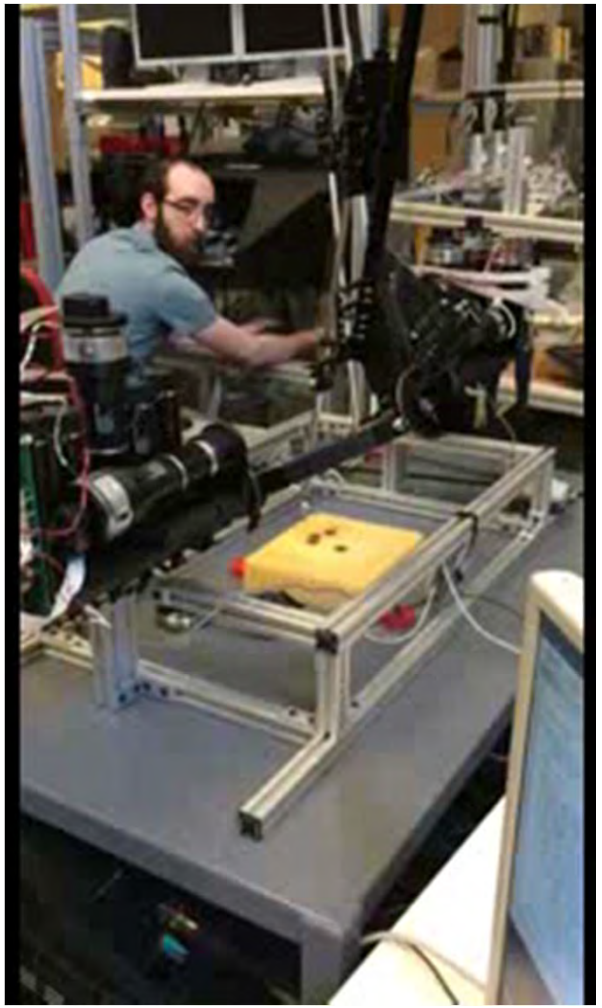


Johns Hopkins University, March 20-21, 2014

Interoperability

da Vinci master teleoperating
Raven II via ROS





Community Research: Learning by Observation

Autonomous Robot Surgery

Performing Surgical Subtasks without Human Intervention
UC Berkeley, October 2014

Adithyavairavan Murali, Siddarth Sen, Ben Kehoe, Animesh Garg,
Seth McFarland, Sachin Patil, W. Douglas Boyd, Susan Lim,
Pieter Abbeel, Ken Goldberg

Berkeley
UNIVERSITY OF CALIFORNIA

Summary

- Open source research platform based on first-generation da Vinci system:
  - Open source electronics
  - Open source software, with ROS interfaces
- Growing user community:
  - 20 sites up and running (internationally)
  - several more in process
- Links:
  - http://research.intusurg.com/dvrkwiki/
  - http://github.com/jhu-cisst (and jhu-saw)
  - http://github.com/jhu-dvrk

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- Firmware: Zihan Chen, Paul Thienphrapa, Long Qian
- Hardware and Testing: Lawton Verner, Ravi Gaddipati, Gang Li, Nirav Patel, Zhixian Zhang, Alex Camillo
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Questions?