Use of Remote Experimentation in the Undergraduate Electrical Engineering Curriculum at CMU

Remote Experiments in Science Education

ALCOM Science & Technology Center

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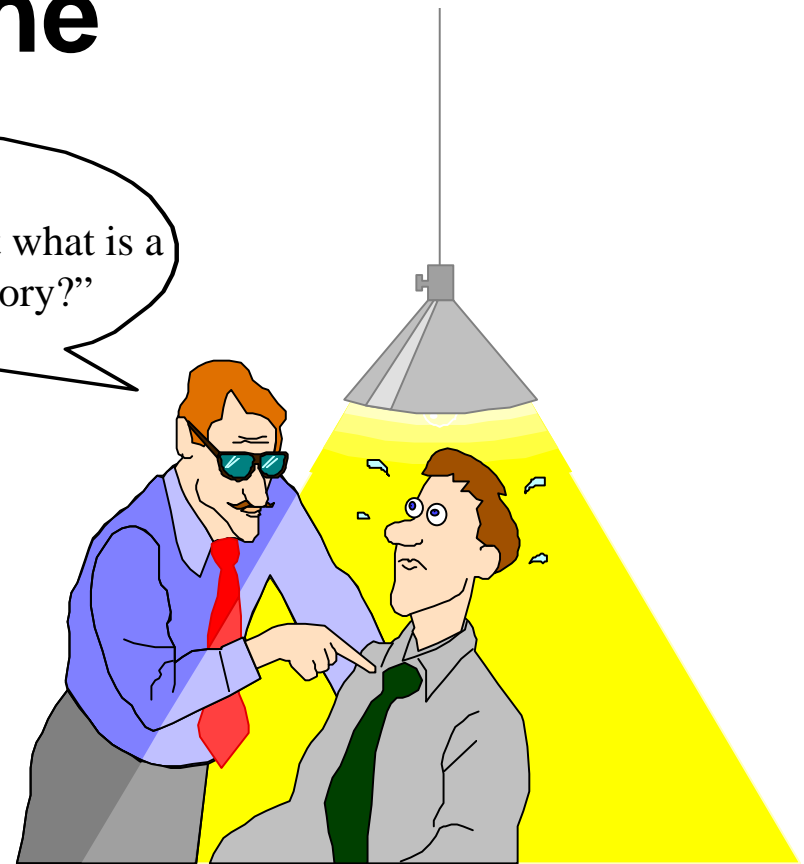
Department of Electrical and Computer Engineering

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Outline

- The Remote Laboratory Concept
- "Virtual Lab" Course Fall 95, 96
- Freshman Introduction to ECE Course, Su99, S00
- Lessons Learned

Ok, buddy, just what is a "virtual laboratory?"

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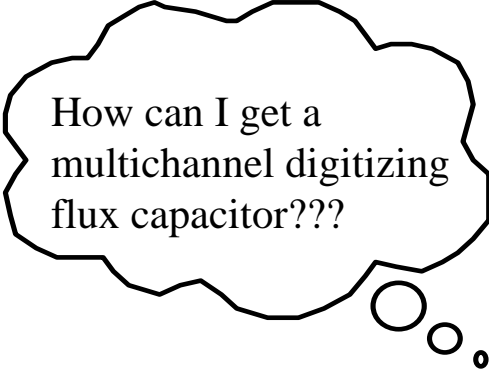
Evolution of the Concept at CMU

- Initial proposal in early 90's by Pradeep Khosla: allow students to check out PC boards that would enable generation & measurement of signals--in dorm or elsewhere ("Virtual Lab")

- Development of integrated simulation and measurement labs for signals & systems

- Remote access prototype demonstrated during ABET visit, F94

- "Virtual Lab" course taught F95, 96

- Advanced semiconductors course: students tested devices after fabrication using remote access to CV analysis instrument, 1999

- Demos and student access in Freshman course Su 99, S00

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Remote Lab Elements and Motivation

- Elements
  - Virtual Instruments
  - Remote access
- Motivation and Applications
  - Training for modes of work in industry
  - Resource Leveraging
  - Educational Enhancements

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Problem: Instrument not Available

- Needs for special purpose instruments may exceed budgets

- Special purpose instruments may not be available in an isolated remote location (e.g., space!)
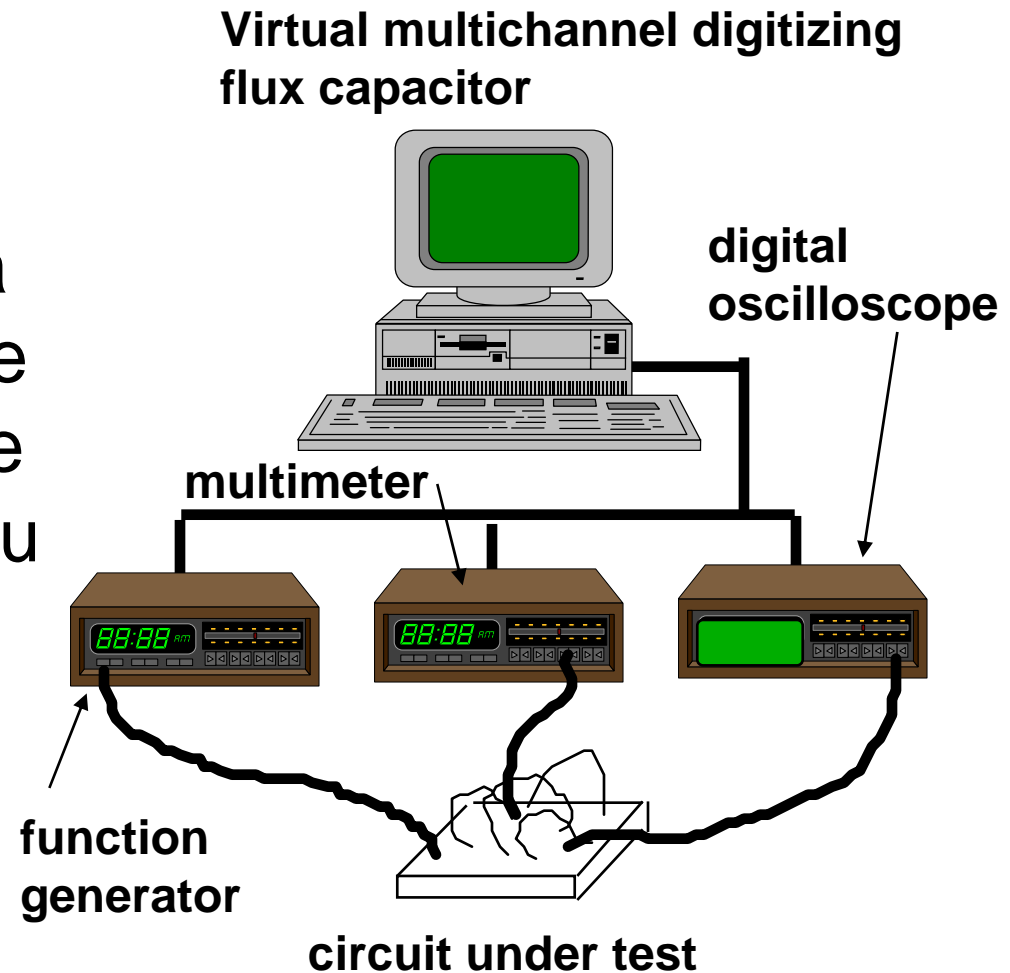
How can I get a multichannel digitizing flux capacitor???
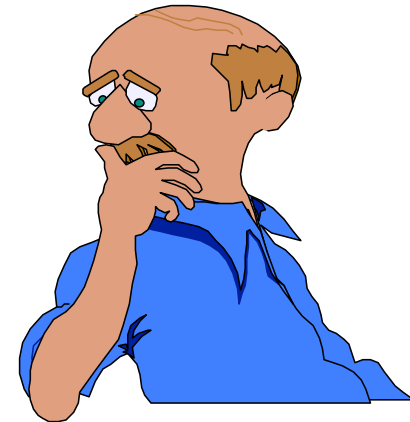
Solution: Virtual Instrument

General purpose instruments can be programmed with a computer to behave like special purpose instruments that you don't have!

Virtual multichannel digitizing flux capacitor

digital oscilloscope

multimeter

**function generator**

circuit under test

Problem: Instruments not Accessible

- Needed instruments exist only at a distant location

- University lab is locked at 3:00am when student wants to do assignment

- University equipment under-utilized outside of scheduled lab times

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Solution: Remote Instrumentation Access

- Students can use university laboratory instruments when the lab is not open

- Instruments can be shared among multiple universities

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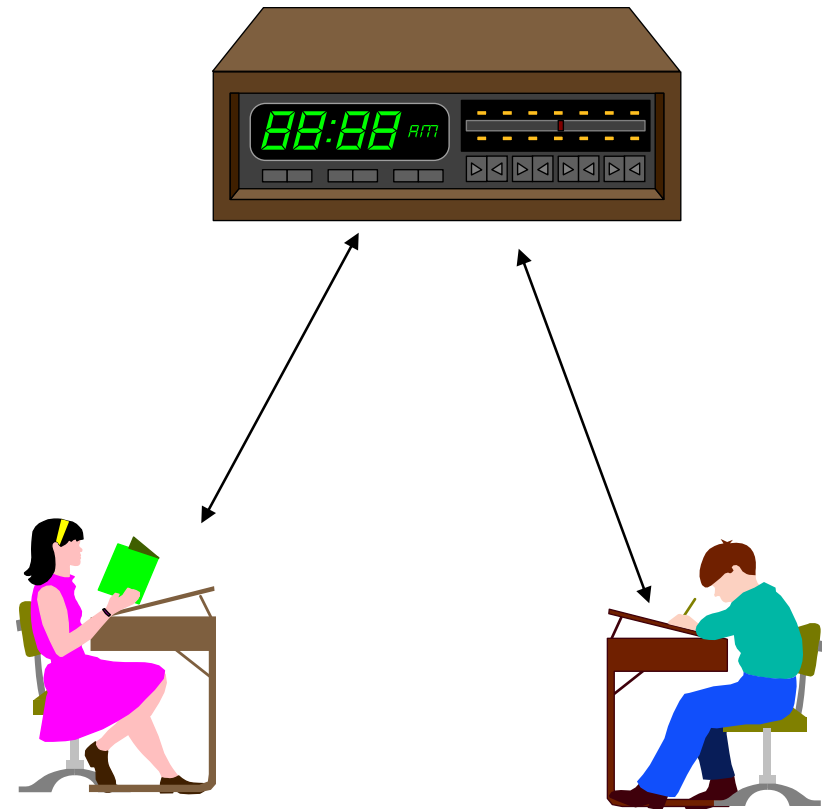
Industrial Application 1

- Adjustments to equipment on a manufacturing line from a central (perhaps remote) location
- ➢ Saves travel time and expense
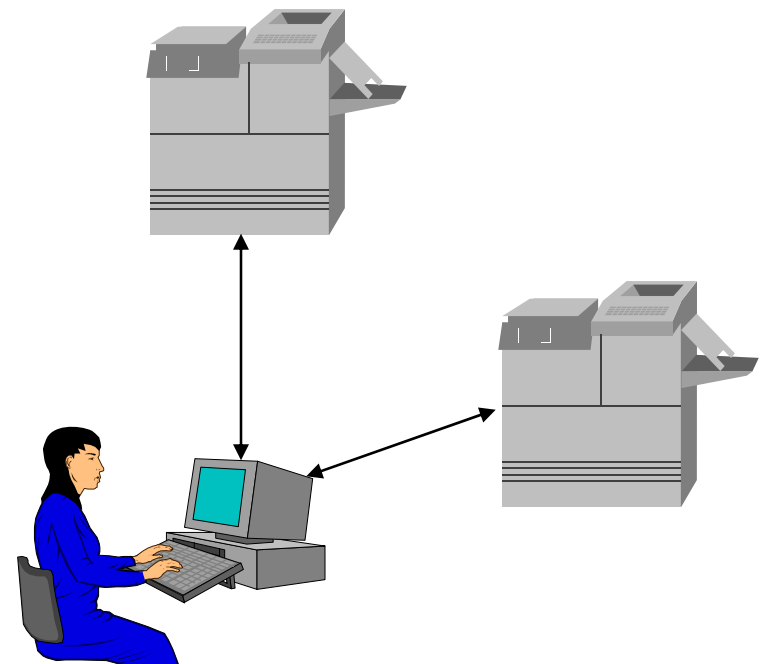
Industrial Application 2
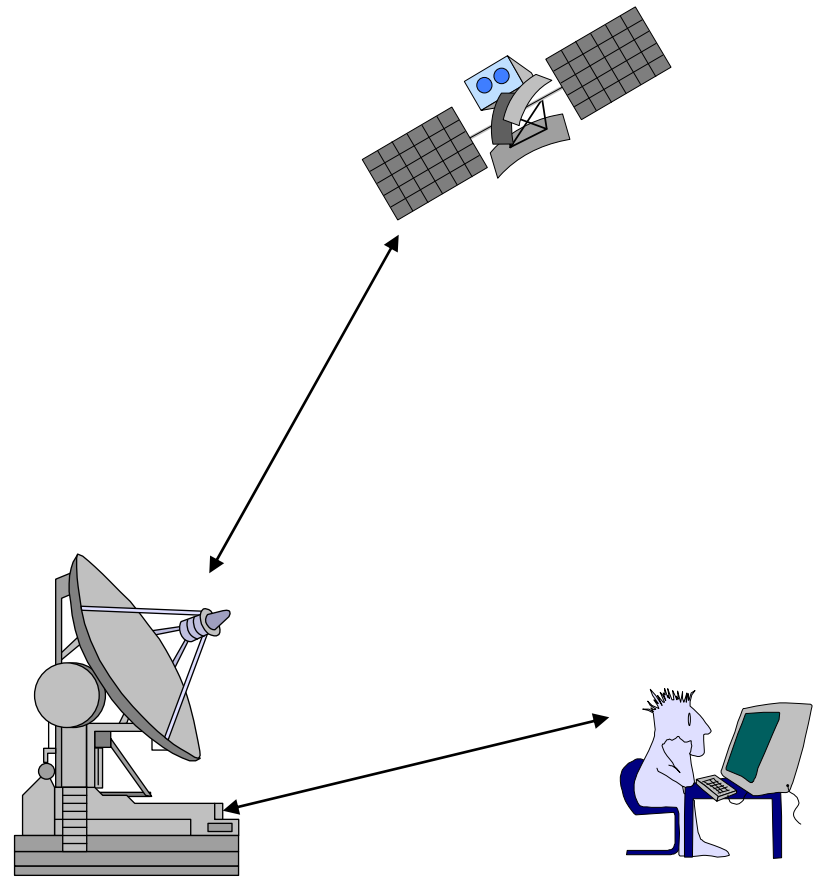
- Support Engineer can make adjustments to client's system remotely
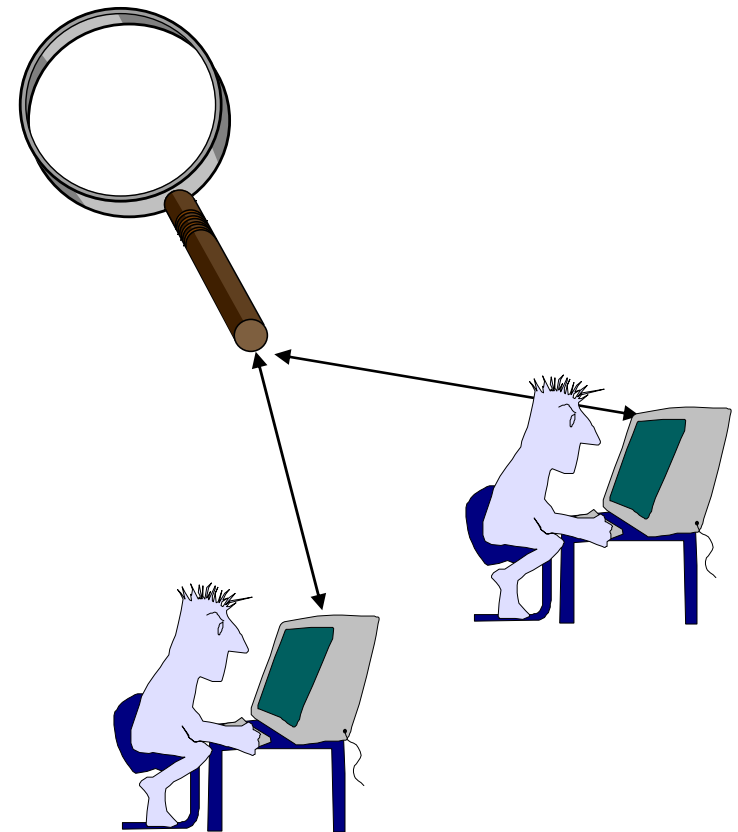- ➢ Saves travel time and expense

Scientific Application 1

- Remote exploration: space, sea, volcanoes, etc.

➢ Travel not physically possible

Scientific Application 2

- Engineers/Scientists have remote access to a large, expensive piece of equipment

➢ saves travel expenses

➢ gives wider access to equipment

Educational Applications

- Training for real-world experiences
- Resource leveraging
  - instrument sharing between schools
  - secure after hours use of existing equipment
- Enhanced Classroom demonstrations
  - avoids logistical difficulties of setting up demo in class
  - allows students to play with demo after class at their leisure
- Enables lab component for distance education

What's in a Name?

- "Virtual Laboratory" is a bit of a misnomer
- We are not *simulating* laboratory experiments
  - We are providing remote access to *real instruments and experiments*
- Perhaps better name: "Telelaboratory"

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Initial Course Experience

- Remote access paradigm is increasingly being used in industry along with telecommuting and teleconferencing

- CMU activity: introduce this paradigm into the undergraduate laboratory experience

- 18-439 Special Topics in ECE: "Advanced ECE Laboratory Techniques: Virtual Laboratory," Fall 1995, Fall 1996, 3 units (=1 credit)

- Much was learned, but enrollment not large enough to justify continued offering

Course Goals

- Increase the usefulness of general purpose test instruments
  - Improved understanding of basic capability
  - Virtual instruments
- Explore remote (virtual laboratory) capability
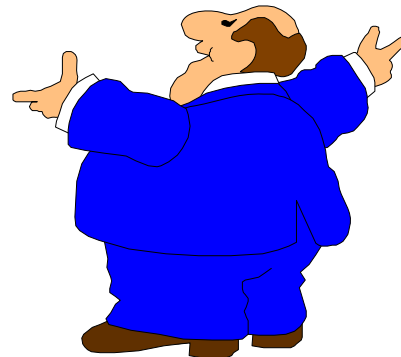
Original CMU ECE Virtual Laboratory

dorm room, office

Internet

LAN

dial-up

wireless

Virtual Instrument

digitizing oscilloscope

multimeter

function generator

circuit under test

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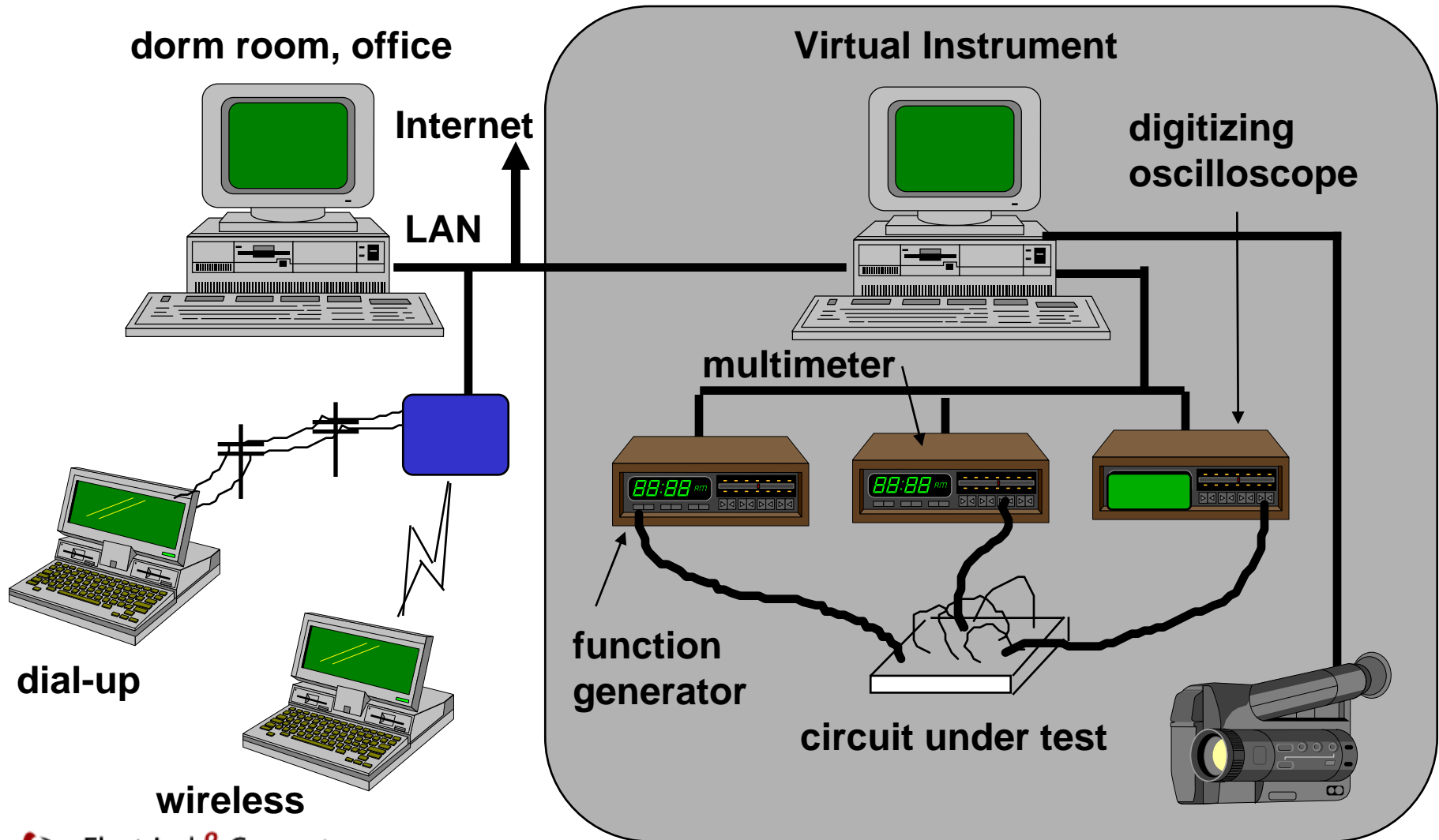
Key Virtual Lab Software

- HP-VEE (Hewlett-Packard)

- QuickCam Software (Connectix)

- Timbuktu (Farallon)

  - Complete cross-platform control from Macs or PCs

- Philosophy: Minimize custom software to make it easy for others to replicate

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Key Virtual Lab Hardware

- PC running Windows, with ethernet, HPIB interfaces
- Digitizing oscilloscopes
- Digital multimeter
- Function generator

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"Black Box" Lab

- Failure has occurred in remote telemetry filter
- Students given correct schematic diagram
- Limited to electrical measurements at input and output ports
- Students must remotely diagnose component failure

Martian Rescue

- Camera positioner failure on Martian Lander

- Students must program a new camera positioner remotely

- Use functioning camera to search for life on Martian landscape
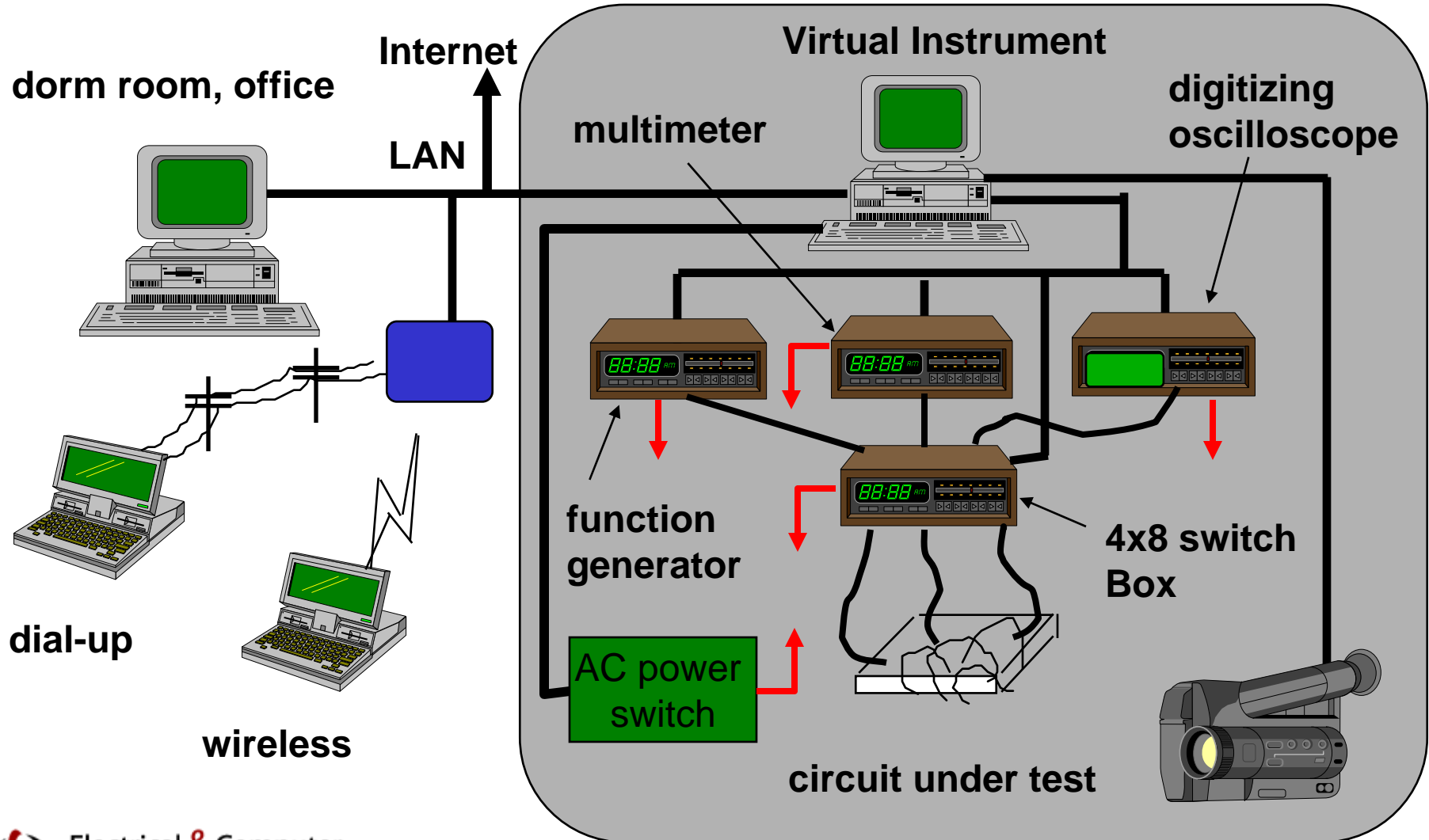

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Freshman Introduction to ECE Summer 1999, Spring 2000

- Updated Lab software and hardware
- Demonstrations used in lecture
- Demonstrations made available online to students after lecture to preview next lab assignment

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Updated Remote Lab

dorm room, office

Internet

LAN

Virtual Instrument

multimeter

digitizing oscilloscope

function generator

4x8 switch Box

dial-up

AC power switch

wireless

circuit under test

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Demo Example: Diode I-V Curve

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Survey Results
1=disagree, 5=agree

Question	Rating
1. The remote lab demonstrations clearly illustrated concepts discussed in the course.	3.45
2. The remote lab displays could be easily seen and interpreted.	3.41
3. The remote lab demonstrations helped me understand course concepts.	2.96
4. The addition of assignments allowing students to conduct remote experiments themselves would be interesting.	3.32
5. Overall, the remote lab demonstrations were a valuable addition to the course.	2.82

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Thoughts on Remote Control

- HP VEE and LabView now allow design of instrument interfaces that can be accessed with only a web browser
  - student doesn't need additional software
  - not as well suited for remote development

- Remote control software
  - allows everything on computer to be controlled-- facilitates remote development
  - Timbuktu: permits cross-platform control (mac-PC)
  - VNC: free

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Wireless Telelaboratory Access

Functional, but not yet exploited....

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Lessons Learned

- The software must be reliable. Frequent software crashes frustrate students.

- If the students do remote development, you must have the ability to power cycle the instruments being controlled to recover from crashes.

- The remote lab must be a required part of the course, or offer clear added value to students. If they don't perceive a significant benefit, they won't use the remote lab.

- Experiments must be sufficiently flexible to allow students to explore a wide range of questions or conditions. "Cookbook" labs with limited flexibility offer little attraction to bright students.

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