

Significance of Online Laboratories in Modern Engineering Education

**Janusz Zalewski
Professor of CS & S/W Eng.
Florida Gulf Coast Univ.
Ft. Myers, FL, USA**





Talk Outline

- Motivation x 3
- Lab Examples
- Impact of Technology
- Conclusion

Motivation x 3



Motivation x 3

Cyberphysical systems
- embedded computing
systems with access to
real physical devices and
connectivity to Internet.

Motivation x 3

- 1) *Professional*
 - 2) *Societal*
 - 3) *Innovational*
- [... Educational ...]*

Complex
Intelligence
Systems Division

Motivation #1

Modern cyberphysical systems involve the most demanding real-time safety-critical applications, such as:

- **flight control systems**
- **accelerator control**
- **sensor networks**
- **navigation, road vehicle control, etc.**

They are all distributed and for proper operation require very different programming techniques than traditional systems.

Motivation #1

Thus, there is unquestionable need to:

- **create a S/W development education laboratory to apply methodologies for implementation and testing of real-time embedded systems**
- **enable web-based development and testing (as opposed to traditional local development), by expanding remote access to operation.**

Motivation #2



T. Berners-Lee, R. Cailliau, Motivation #2

World Wide Web:

Proposal for a Hypertext Project: CERN

- **Nov. 12, 1990, Geneva, Switzerland**
- **Operation: “A link is specified as an ASCII string from which the browser can deduce a suitable method of contacting an appropriate server. When a link is followed, the browser addresses the request for the node to the server.”**

Motivation #3



Top Tech 2012 Special Report

IEEE Spectrum, January 2012

- **Bye, Wheelchair, Hello Exoskeleton**
- **3-D Chips Grop up**
- **Birth of the Bionic Eye**
- **China's Homegrown Supercomputers**
- **Plug-in Vehicles Proliferate**
- **3-D Printing Takes Shape**
- **4G LTE (Long Term Evolution) networks**

2014 Top Tech To Watch

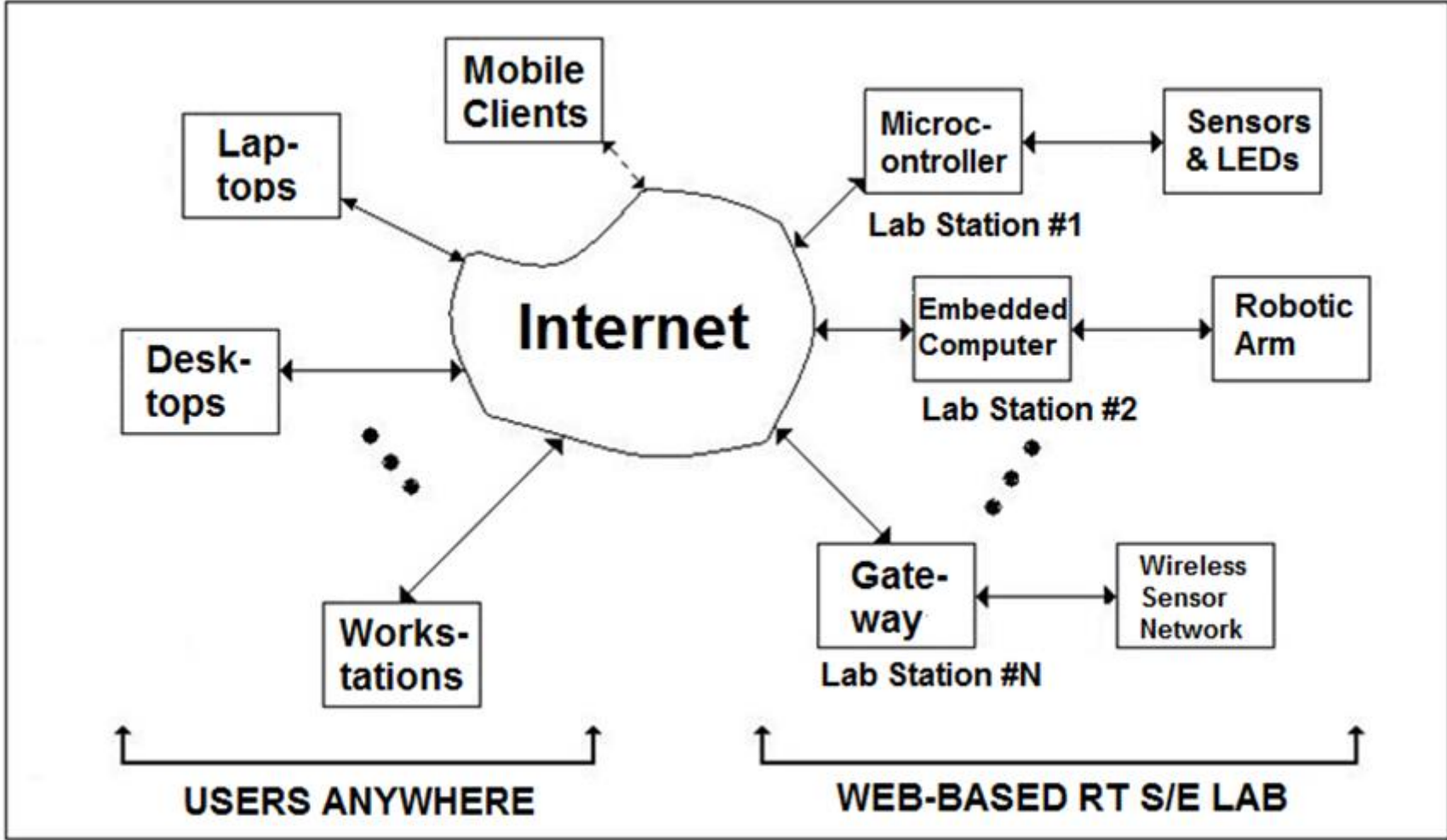
IEEE Spectrum, January 2014

- **Would You Shoot Neighbor's Drone?**
 - **Oculus Virtual Reality**
 - **LTE Advanced: Real 4G**
 - **Formula E Cars**
 - **U.S. Brain Initiative**
 - **China: Next Space Superpower**
- 
- A blue MHWA 1670 U.S. Air Force locomotive is shown in a grassy field. A man in a red shirt and blue jeans is standing on the yellow platform of the locomotive. The locomotive has "MHWA 1670" and "U.S. AIR FORCE" written on its side. The background shows trees and a clear sky.

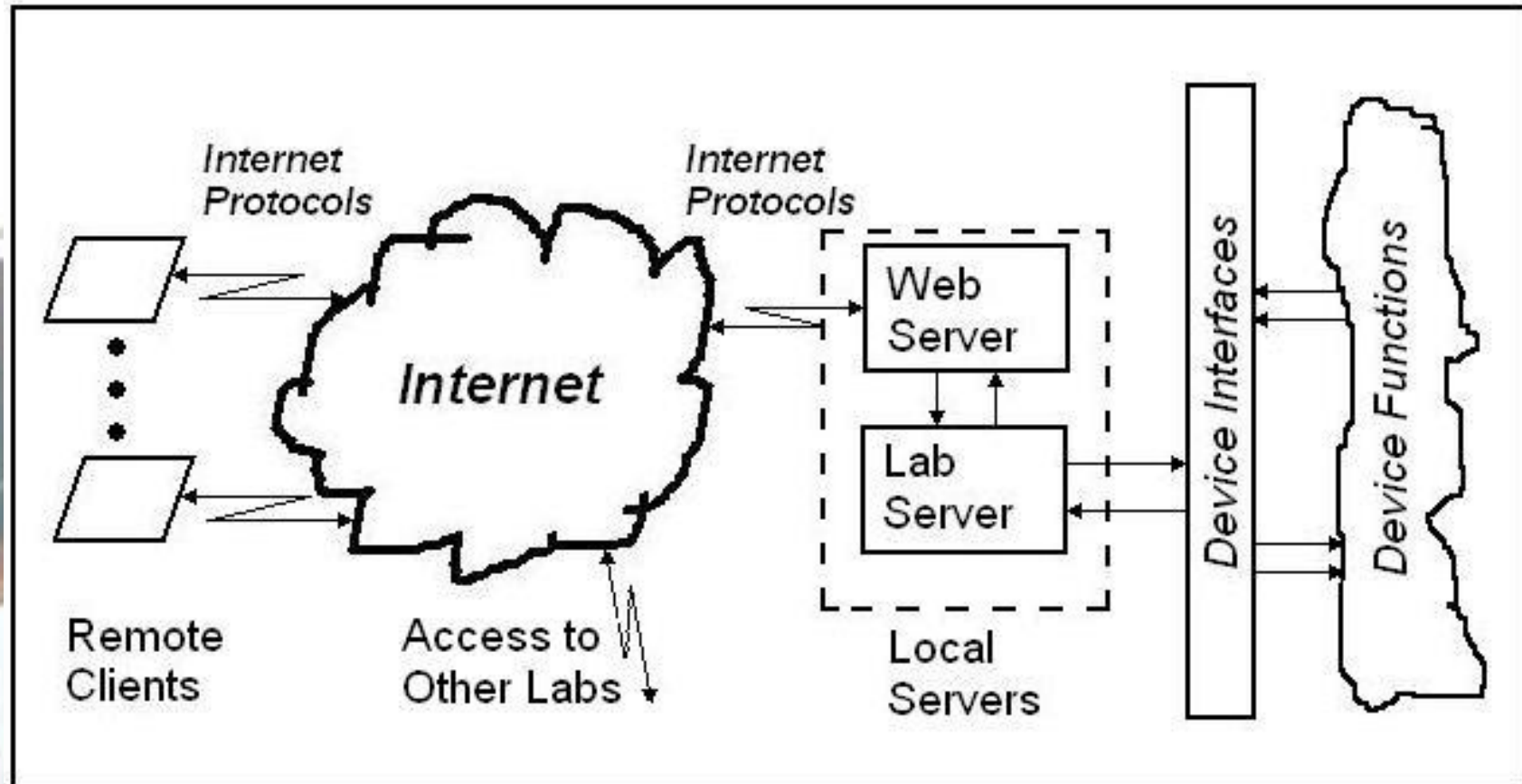
Lab Architecture & Stations



Lab Architecture & Stations



Lab Architecture & Stations



What Sort of Online Labs?

All Non-invasive:

- **Batch (observation)**
- Interactive (setting parameters)
- Sensor (data collection)

How about Invasive Labs?

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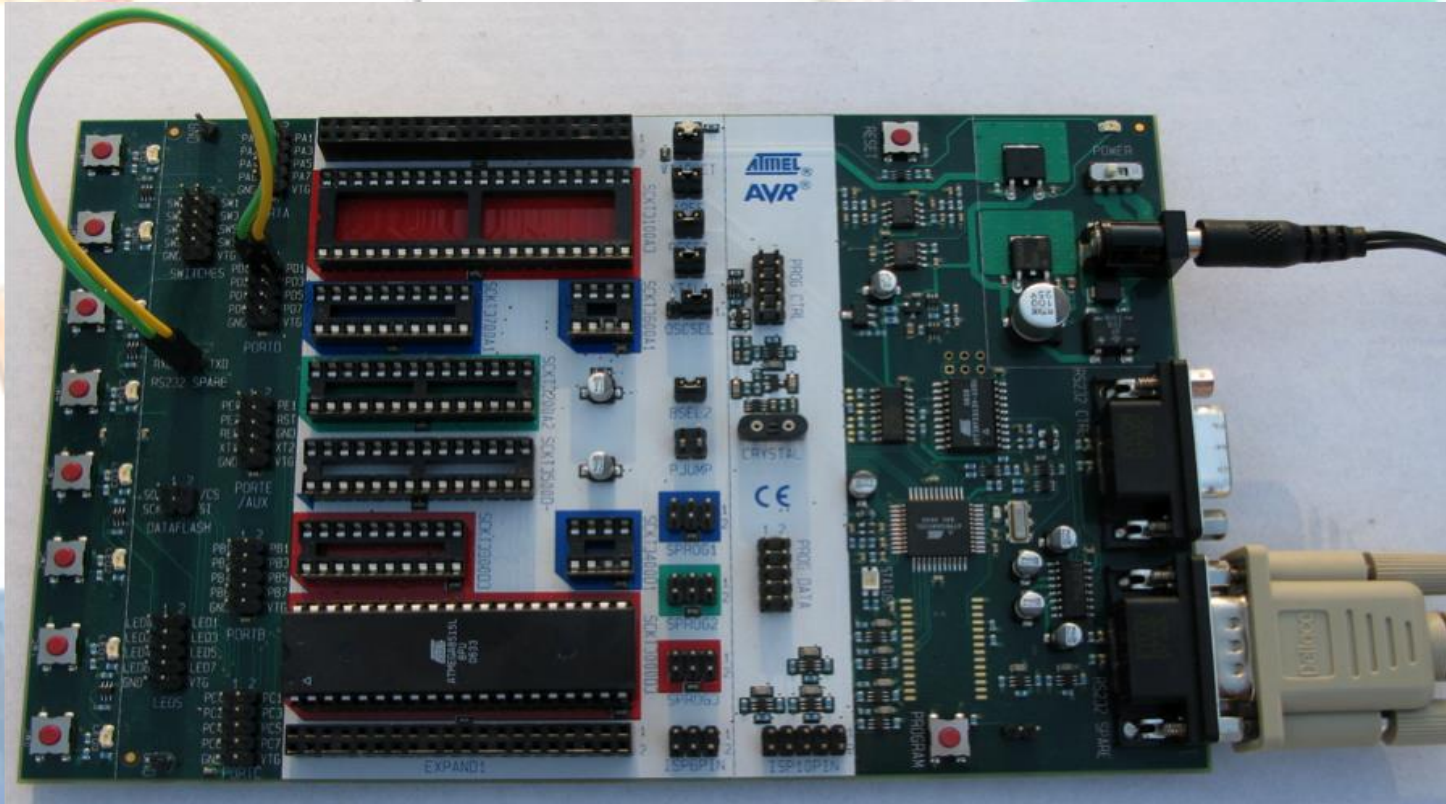
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How about Invasive Labs?

Station 1: Remote μ controller



Station 1: Remote μ controller

Specific Tasks (ATMEL μ C):

- **data acquisition: temp. sensor**
- **communication: serial port**
- **developing remote server in C**
 - **configuring the server**
 - **uploading the server S/W**
- **building client & GUI access.**

Station 1: Remote μ controller

Networking a Microcontroller - Windows Internet Explorer
http://69.88.163.18/vincent/index.html

Atmel AVR STK500

Web Access and Remote Programming



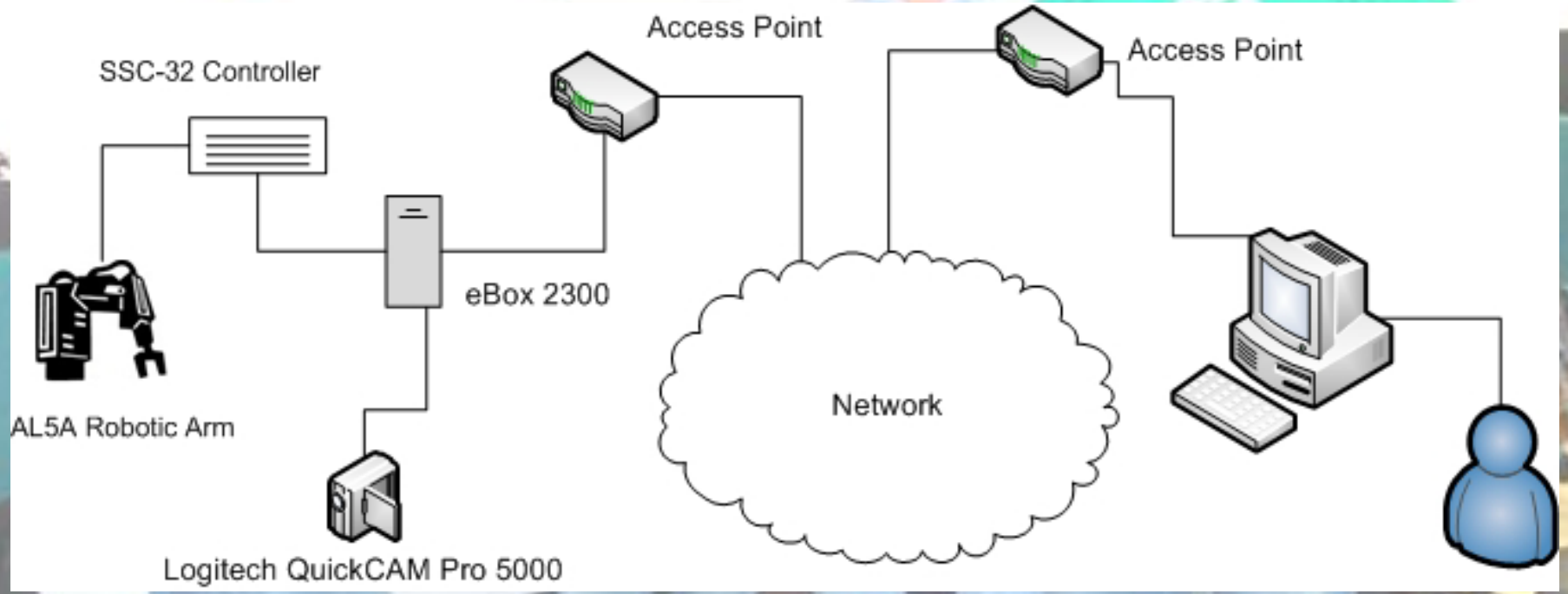
Last 10 Temperature Readings

[Click here to download all recorded temperature readings](#)

Load a HEX Application File to Program the Board
Filename (.hex only):

Done Internet 100%

Station 2: Remote Robotics



Station 2: Remote Robotics

Specific Tasks:

- **control system: servo motor**
- **data acquisition: temp. sensor**
- **building remote server in C#**
 - **configuring and deploying CE**
 - **uploading the server software**
- **building local client & GUI in C#.**

Station 2: Remote Robotics

eBox Remote Station Control

PLEASE DON'T USE IT FOR MORE THAN 5 MIN.
GIVE OTHERS THE CHANCE TOO!

Up
Left Right
Down
Servo Control

Still Capture
SnapShot

Temperature Panel
Read
Disconnect Alarm

Connection Panel
eBox 2300 IP: 69.88.163.25
Port: 18888
Connect Disconnect CLOSE

Remote Station Control

Station 3: Sensor Network

The image is a composite showing a physical hardware setup on the left and a LabVIEW software interface on the right. The hardware setup features two National Instruments (NI) wireless routers connected to a breadboard with electronic components. The software interface is a LabVIEW project titled 'Wireless Sensor Network' with a 'Waveform Chart' and several 'Controls' palettes.

Hardware Setup (Left): Two NI wireless routers are connected to a breadboard with electronic components. The routers are connected to a central breadboard, which is connected to a power source. The breadboard contains several integrated circuits and resistors.

Software Interface (Right): The LabVIEW software interface shows a project titled 'Wireless Sensor Network'. The 'Project Explorer' on the left lists the following items:

- Build Specifications
- NI-WSN9791-014C6762 (169.254.3.242)
- Wireless Sensor Network
 - Node1 (ID 1, 14D8CAE, NI WSN-3202)
 - AI1
 - AI2
 - AI3
 - Battery Voltage
 - DI00
 - DI01
 - DI02
 - DI03
 - External Power
 - Link Quality
 - Mesh Router
 - VI Deployed
 - Node2 (ID 2, 14C307F, NI WSN-3212)

The main workspace displays a 'Waveform Chart' with 'Amplitude' on the y-axis (ranging from -10 to 10) and 'Time' on the x-axis (ranging from 0 to 100). The chart is currently empty. Several 'Controls' palettes are open, showing various control elements like 'Modern', 'Silver', 'System', 'Classic', and 'Express'.

Station 3: Sensor Network

Specific Tasks:

- **Zigbee/IEEE Std 802.15.4**
- **communication: sockets**
- **double role of the project**
 - **programming in LabVIEW**
 - **web access for testing.**

Station 4: Remote FPGA

Please Logout when you are finished.



Station 4: Remote FPGA

Specific Tasks (Altera & Xilinx):

- **control: servo & webcam**
- **communication: USB port**
- **double role of the project**
 - **developing the remote access**
 - **programming FPGA's in VHDL**
- **FPGA display/LED's.**

Station 5: Web Game

HydraNet 3 Player

The game controls are:

- A: Left
- D: Right
- W: Up
- S: Down
- J: Action

To play, you must first click within the screen area.



Game uploader

To upload a game for the HydraNet 3 system, three files are required:

- Compiled game file.
- Zipped images file.
- Game manual file.

Select the files and then click the "Upload Files" button:

Compiled game file (.eprom)

Zipped images file (.zip)

Game manual file (.txt)

Station 5: Web Game

Specific Tasks:

- **8-core Parallax Processor**
- **communication: HTTP**
- **double role of the project**
 - **programming the game**
 - **web access for testing.**

Station 6: Remote Testing



Station 6: Remote Testing

Specific Tasks (VxWorks):

- **embedded controller: PowerPC**
- **communication: sockets & RPC**
- **double role of the project**
 - **programming under VxWorks**
 - **web access for testing**
- **data acquisition devices.**

Introducing Learning Objects

- ***An entity (most commonly, a device) encapsulating certain educational functions***
- ***Examples: cell phone, robot, website***
- ***Accessible only via its well defined interfaces, that is, functions to perform pre-determined learning activities***
- ***A student interacts with a LO only by using interfaces.***

Introducing Learning Objects

- ***Robotic devices***
- ***Sensors***
- ***Sensor networks***
- ***Games***
- ***Solar plants***
- ***others.***

Remote Learning Objects

- ***IEEE Standards Association***
- ***Working Group P1876***
- ***Networked Smart Learning Objects for Online Laboratories***
- ***<http://iee-sa.centraldesktop.com/1876public>***

 **Fermilab**

Managed by Fermi Research Alliance
For  Office of Science/US Department of Energy



Lewis Mumford (1920's)

megamachine

A shorthand reference to the entire technological complex.

Lewis Mumford (1920's)

megamachine

A shorthand reference to the entire technological complex.

-- building the pyramids

Lewis Mumford (1920's)

megamachine

A shorthand reference to the entire technological complex.

[Space Shuttle, Dreamliner, LHC]

Some Data

- **Facebook, March 2013 – 665 million users per day**
- **In 2014 – 7.4 billion of active mobile phones**
- **In 2025 – 7 trillion IP enabled devices**

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More Data

- **Typical Japanese aircraft involves 200,000 parts, 10 times more than a car, which involves 20,000 parts**
- **In 1900's it took 700 parts for Ford to produce Model T**
- **In 1990 at Super Collider the plan was to have particles collide every 10-100 ns producing 1 MB of data each time**

- New Technology has an impact:
... the clock is not merely a means of keeping track of hours but of synchronizing the actions of men

- **New Technology has an impact:**
... the clock is not merely a means of keeping track of hours but of synchronizing the actions of men [...] one ate not upon feeling hungry but when prompted [...]; one slept not when one was tired...
[Lewis Mumford, 1936]

Marshall McLuhan (1960's)

the medium is the message

“after more than a century of electric technology, we have extended our central nervous system into global embrace”

Some Facts

- **Wheels extend our legs**
- **Glasses are extending our vision**
- **Printing extended our speech**

Some Facts

- **Glasses are extending our vision**
- **Vehicles extend our legs**
- **Printing extended our speech**

More Facts

- **Printing press gave rise to revolution in communication**
- as a consequence, the emergence of rational thought in Enlightenment was actually due to the printing press
- **Telegraph, telephone extend our nervous system**
- **Electronic media extend our consciousness**

the medium is the message

What is actually in the contents of the *message* is not important. It's the *medium* which contains, conveys and is the *message*.

the medium is the message

When Jim and Joe go to Starbucks to logon to the remote lab and see whose program controls better a robotic arm, what happens is that they use *medium as the message*.

Disruptive Technologies

- **mechanical clock (Mumford)**
- **printing press (McLuhan)**
- **steam engine (control device)**

all caused revolutionary changes...

Disruptive Technologies

Cause failures of industries

- Sears gave way to Walmart**
- Blockbuster gave way to Netflix**

due to revolutionary changes...

Disruptive Technologies

Cause failures of industries

- **IBM missed the minicomputers**
- **DEC missed the microcomputers**

due to revolutionary changes...

C.M. Christensen

disruptive technology

The technology that has a potential to disrupt the markets, because they have not been prepared for its introduction.

Ryszard Kapuściński

In “The Shadow of the Sun” (1991)
- Polish title “Heban” (1998) - gives
an example of introducing plastic
containers that dramatically
changed lives of women in Africa.



Conclusion

- ***New Disruptive Technology***

Technology that has a potential to disrupt markets, because they have not been prepared for its introduction.

[Bowen & Christensen, 1995]

Conclusion

- ***New Disruptive Technology***
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[Lewis Mumford, 1936]

Conclusion

- **New Disruptive Technology**
- **Tremendous job advantage for student developers**
- **Great experience for faculty**
- **Significant technical problems**
- **Major administrative problems**
- **Course on Embedded Systems Programming in Spring 2013**

Waiting for Questions

